EFFECT OF DRAWING TEMPERATURE
ON THE
PHYSICAL PROPERTIES OF SPECIAL STEELS

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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THE EFFECT OF THE DRAWING TEMPERATURE ON THE PHYSICAL PROPERTIES OF SOME SPECIAL STEELS

A THESIS

PRESENTED BY

DONALD A. DROZESKI

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MECHANICAL ENGINEERING

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The author of this report is greatly indebted to Mr.Daniel Roesch for his many suggestions and the valuable assistance that he gave during the entire test.

He is also deepely indebted to Mr. H.B. Pulsifer for the chemical analysis of two of the specimens.

INTRODUCTION.

With the perfection of high speed machinery it has become necessary to make the parts as light as possible, and yet to maintain the necessary strength. This has led to the manufacture of steels having a high tensile strength. But to get the full benefit of these steels it is necessary to heat treat them in the proper way.

This treatment varies with the different steels and it has been the object of this thesis to find the treatment necessary to give the required properties to the steels under discussion.

OBJECT

The object of these experiments was to determine the effect of the drawing temperature on the physical properties of some heat treated steels.

SPECIMENS

The steels were of regular mill stock. The Nickel Chrome Vanadium was obtained thru the courtesy of Mr. H.L. Baker from the Chicago office of the Carnegie Steel Co. The other steels were obtained thru the courtesy of Mr.M.J. Murphy from the Chicago Drop Forge and Foundry Co.

The tests were made on four kinds of steel the same procedure being carried out with each kind. The first steel tested was what is known as a Nickel steel, and was supposed tomcontain 3 1/2 % Nickel

The second specimen was given to us as a .30-.40 carbon steelbut on analysis

was found to contain the following elements

Carbon	.23 %
Nickel	4.30 %
Chromium	.20 %
Vanadium	.026%
Tungsten	.00 %

The third steel was given to us as a .40-.50 carbon steel but on analysis was found to contain the following elements :

Carbon	.49 %
Nickel	.00 %
Chromium	.10 %
Vanadium	.013%
Tungsten	.00 %

The Nickel Chrome Vanadium was given to us under the following guarantee as to analysis :

Brand S. Regular	
Carbon	.20-.30 %
Nickel	.70 %
Chromium	.75-1.25 %
Vanadium added	.16-.20 %
Silicon	.20 %
Manganese	.20-.40 %
Phosphorous & Sulphur	less than .04 %

METHOD

The specimens were first turned to size in the machine shop; after which they were heat treated, and then tested for hardness and tensile strength.

The machined specimens were first annealed at 750 C. to insure a uniformity of all specimens. After this they were all treated in the same general way; which was to heat, quench, and draw.

The 3 1/2 % nickel, the .30-.40 carbon, and the .40-.50 carbon were treated in the following way. All the specimens were heated to 875 C. and allowed to soak for fifteen minutes at this temperature, then plunged in water and left until cold. One specimen of each material was then heated to 400, 500, 600, and 700 degrees centegrade thus making a total of twelve pieces.

The Nickel Chrome Vanadium specimens were divided into four lots of three specimens each. All these specimens were heated to 850 C. and allowed to soak fifteen minutes

then quenched in water . The drawing temperatures in each lot were 500, 600, and 700 degrees centegrade.

Each piece in the first lot was heated to 850 C.and quenched, then drawn to the desired temperature. This treatment is known as a single quench and single draw.

In the second lot each piece was heated to 850 C. and quenched, then drawn back to the desired temperature twice. This treatment is known as single quench and double draw.

In the third lot each piece was heated to 850 C. and quenched, then brought up to the same temperature again and quenched; after which it was drawn to the desired temperature once. This treatment is known as double quench and single draw.

In the fourth lot each piece was heated to 850 C.quenched, heated to the same temperature again and quenched a second time after which it was drawn to the desired temperature twice. This treatment is known as double quench and double draw.

Three special tests were now made by quenching the steel in oil and giving it no draw at all. For these tests a nickel and a .40-.50 carbon specimen were heated to 875 C. and quenched in Fish oil and a .40-.50 carbon heated to 875 C. and quenched in a mineral oil.

APPARATUS

Furnace.

The furnace used was electric, of the carbon plate resistance type the general arrangement of which is shown in the picture. On the inside the furnace is twelve by six and one half by five and one half inches with a suspended door in the front and a small hole in the rear for inserting the pyrometer. On the inside of the furnace the two side walls are built up of carbon plates with a heavy carbon plate connecting the two sides across the top. The bottom plates on both sides are extra heavy and the current is brought to them thru a heavy round carbon. This carbon is placed vertically and mooved up and down by a screw from below. By adjusting this screw the resistance of the plates above is adjusted. When the plates are tight together the resistance is lowered thus increasing the flow of current which in turn increases the heating effect. This arrangement makes the adjustment very satisfactory

for it was easy to maintain a constant temperature within a range of three degrees Centegrade. A three phase alternating current was used which was stepped down to fifteen volts from the line voltage of eleven hundred volts.

Pyrometer.

A Whipple platinum resistance pyrometer was used which was standardized against substances of known melting points before the run. The fire end of the pyrometer was placed thru a one inch hole in the back of the furnace and projected into the furnace about eight inches. This end was about two inches above the specimens so that the temperature of the pyrometer wasthe same as that of the steel. The temperature thruout the furnace was found to be very uniform thus giving the specimens a uniform heating.

Hardness.

All specimens were tested for hardness with "The Shore Sclerescope". The principle of the Sclerescope consists of dropping a miniature tup from a fixed height onto the surface of the material, the hardnessof which is to be measured. This hammer is allowed to drop from a constant height and after striking the piece always rebounds to a height depending on the hardness of the material. The scale of the sclerescope is divided into one hundred and fourty parts which causes the hundred mark to be the point of rebound for hardened tool steel. A piece of steel above 50-60 hard can only be finished by grinding for it is too hard to machine.

Testing Machine

The 60,000 pound Olsen testing machine was used for all the tensile tests. This machine is of the standard type and was calibrated with standard weights before the test. The error and sensitiveness was found to be

less than 1/3 of one percent. It was necesary to make new holders for the specimens of nickel steel heat treated to give the required strength. When run by power the speed of the draw head was eight hundredths of an inch per minute..

The Extensometer.

The extensometer was used for measuring the elongation of the test specimen. The instrument is very simple in operation and the position on the test specimen is shown in the accompanying picture. Before using; the instrument was calibrated with a micrometer screw and found to be correct. The lower part of the instrumentcarrying the scale is clamped rigidly to the specimen. At the other end the pointers are carried. The moovement ofthe pointers is caused by a diamond shaped knife edge fastened to the pointers. The outer knife edge remains in a fixed position on the frame of the instrument while the inner edge mooves as the piece elongates. Thus a slight moovement of the

specimen causes a large moovement at the end of the pointer which can be readily noted. When the pointers are placed on zero the distance between the lower clamped points and the moovable knife edges is two inches. The scale over which the pointers travel is divided into spaces of hundredths and thousandths of an inch of stretch of the specimen, while the nearest ten thousandths can be estimated. The readings were all made thru a telescope thus magnifying the moovement of the pointers and at the same time keeping the line of sight always perpendicular to the scale. The extreme range of the instrament was for a stretch of six hundreths of an inch after which the extension was taken with a pair of calipers.

DISCUSSION.

All the pieces were tested for hardness with the sclerescope.. The test for hardness was taken at three points on the finished portion of the specimen, as far apart as possible, and the average recorded.

Trying the hardness at different points on the same piece gave values that checked closely with each other; the variation being less than two points. All the sclerescope tests were made before the piece was tested in tension.

The extension was noted for every two thousand pounds increase of load up to the elastic limit, after which the maximum and the breaking loads were noted with the corresponding extensions. The curves for specimen No. 34 may be taken as a typical example of the way the specimens acted. The curves were ploted with the load in pounds per square inch on the vertical axis, and the

extension per inch of lengthon the horizontal axis. The upper curve shows the complete performance of the piece; while the lower one shows only the action up to the elastic limit. In the second case the vertical scale is left the same but the horizontal scale is increased ten times. This was done to show more clearly where the curve left the straight line, which point indicates the load at which the elastic limit is reached. It wil be noted that the first part of the curve is a straight line which is accordingto Hook's law. When this law no longer holds the piece has passed the elastic limit and received a permenant set.

It will be noted on the curve that the load increased up to 136,000 pounds per square inch after which it dropped to 134,000 pounds per square inch then rose to the maximum value of 141,000 pounds per square inch from which point the load

gradually dropped off until the specimen broke at a load of 82,000 pounds per square inch. This procedure was characteristic of all the specimens. The reason the load decreased after the maximum value was reached was because the piece was elongating thus reducing the cross sectional area.

The results obtained from each steel are shown on the curves I to VII inclusive. The curves representing the different properties of each steel are shown on the same page showing graphically the effect of the drawing temperature on the different properties. Similar properties acted in approximately the same way for all steels. Thus it will be noted that the hardness, tensile strength, and elastic limit all decreased as the drawing temperature was increased. While the elongation and reduction of area both increased as the drawing temperature was raised.

The greatest strength was found in the .40-.50 carbon steel drawn at 400 C.

It also should be noted for this steel that the range of values for all the properties is the greatest.

In the Nickel Chrome Vanadium steel it was found that the double quenching and double drawing have no material effect on the physical properties.

Specimens No. 17, 22, and 25 were only quenched in oil before testing. The first two were quenched in fish oiland the third in a mineral oil.

No. 17 was a specimen containing 3 1/2% nickel, and comparing it with the nickel specimen quenched in water and drawn at 400 C we find the specimen quenched in oil has a higher maximum load but a lower elastic limit while the other properties remain about the same.

No. 22 was a specimen containing .40-.50 carbon and comparing this with the same material quenched in water and drawn at 400 C

it will be noted that the maximum load is much lower and that the elastic limit is slightly more than half that of the carbon specimen. On the other hand the elongation and reduction of area are increased and the hardnessis decreased, in the specimen quenched in oil.

Specimen No. 25 was the same as specimen No. 22 but was quenched in a mineral oil. The maximum load as wellas the elastic limit were lower in this specimen than the one quenched in fish oil while the other properties remained about the same.

Hook Tests

As extra tests four hooks were made, two of a low carbon steel and two of the Nickel Chrome Vanadium steel. These were then heat treated and tested for strength. The accompanying drawing shows the general shape and size of the hooks.

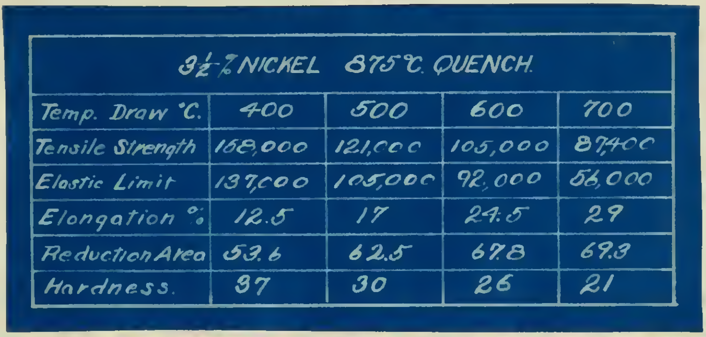
All the hooks were heated to 875 C. Then the two Nickel Chrome Vanadium and one carbon hook were quenched in water while the remaining carbon hook was allowed to cool in the air. The carbon hooks were then tested without further treatment. The Nickel Chrome Vanadium hook No. 1 was drawn to 500 C and the No 2 drawn to 400 C.

The complete results obtained by testing these hooks are shown in the accompanying table. These results show the value of the heat treatment; for even the low carbon hook was greatly increased in strength by this process. The Nickel Chrome Vanadium hook that was drawn at 400 C is probably too hard for good service and the 500 C draw

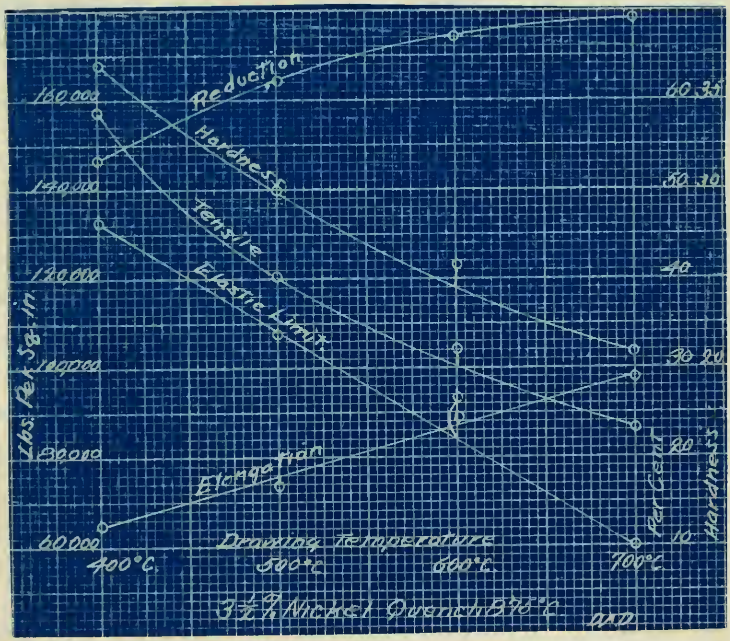
would the better treatment. The higher drawing temperature is necessary because a hook should not break but rather fail by straightening out.

No. I

3 1/2 % NICKEL
875 C Quench



$3\frac{1}{2}$% NICKEL 875°C. QUENCH				
Temp. Draw °C.	400	500	600	700
Tensile Strength	168,000	121,000	105,000	87,400
Elastic Limit	137,000	105,000	92,000	56,000
Elongation %	12.5	17	24.5	29
Reduction Area	53.6	62.5	67.8	69.3
Hardness.	37	30	26	21



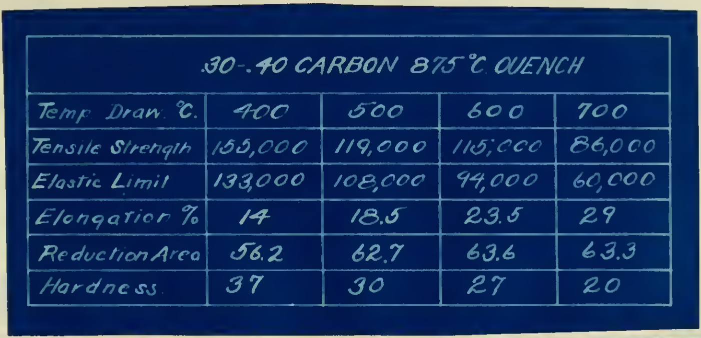
No.2

This steel was supposed to contain .30-.40 carbon but on analysis was found to contain the following elements:

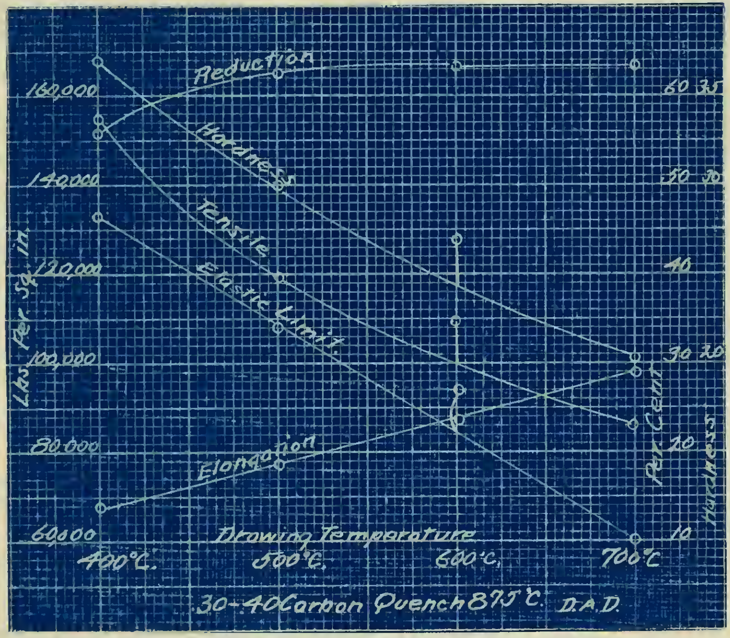
Carbon	.23 %
Nickel	4.30 %
Chromium	.20 %
Vanadium	.026 %
Tungston	.00 %

No. 2

.30-.40 CARBON
875 C Quench



.30-.40 CARBON 875°C. QUENCH				
Temp. Draw. °C.	400	500	600	700
Tensile Strength	155,000	119,000	115,000	86,000
Elastic Limit	133,000	108,000	94,000	60,000
Elongation %	14	18.5	23.5	29
Reduction Area	56.2	62.7	63.6	63.3
Hardness	37	30	27	20



30-.40 Carbon Quench 875°C. D.A.D.

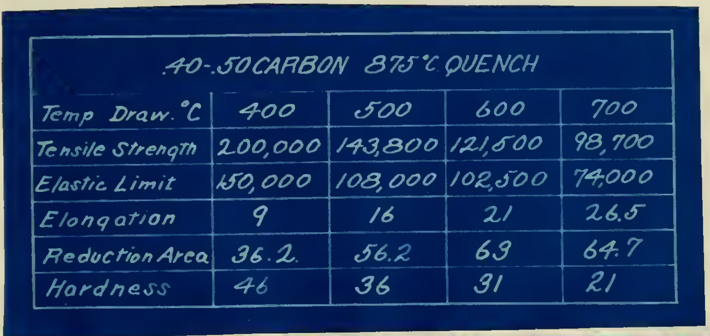
No. 3

This steel was supposed to contain .40-.50 carbon but on analysis was found to contain the following elements :

Carbon	.49 %
Nickel	.00 %
Chromium	.10 %
Vanadium	.013 %
Tungsten	.00 %

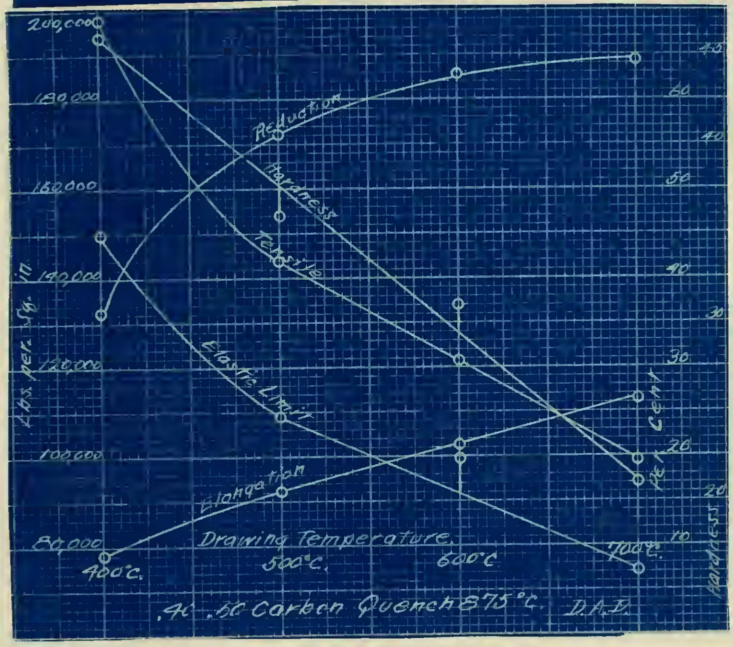
No. 3

.40-.50 CARBON
875 C Quench



.40-.50 CARBON 875°C. QUENCH

Temp Draw. °C	400	500	600	700
Tensile Strength	200,000	143,800	121,500	98,700
Elastic Limit	150,000	108,000	102,500	74,000
Elongation	9	16	21	26.5
Reduction Area	36.2	56.2	63	64.7
Hardness	46	36	31	21

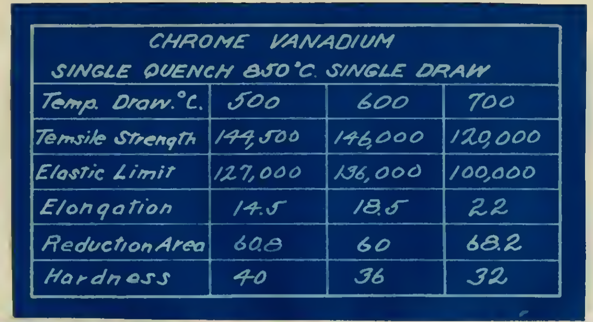


The analysis of the Nickel Chrome Vanadium steel is as follows :

Carbon	.20-.30 %
Nickel	.70 %
Chromium	.75- 1.25 %
Vanadium added	.16-.20 %
Silicon	.20 %
Manganese	.20-.40 %
Phosporous & Sulphur	less than .04 %

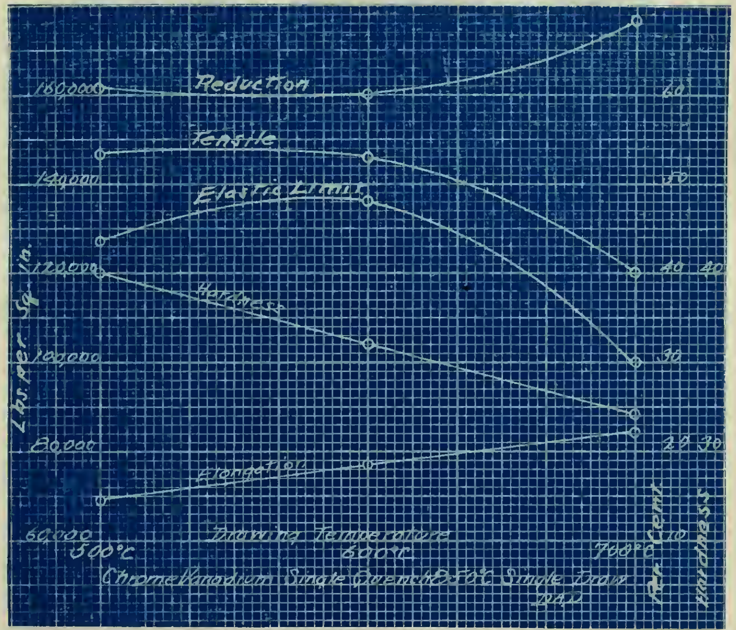
No. 4

NICKEL CHROME VANADIUM
Single Quench 850 C Single Draw



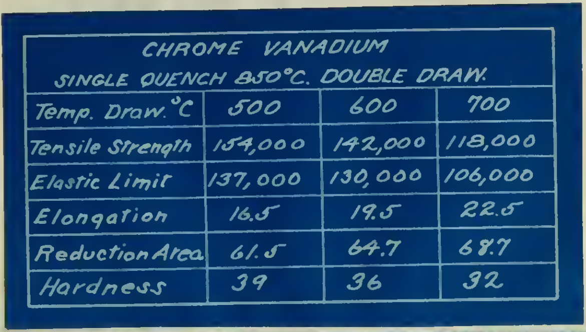
CHROME VANADIUM
SINGLE QUENCH 850°C. SINGLE DRAW

Temp. Draw. °C.	500	600	700
Temsile Strength	144,500	146,000	120,000
Elastic Limit	127,000	136,000	100,000
Elongation	14.5	18.5	22
Reduction Area	60.8	60	68.2
Hardness	40	36	32



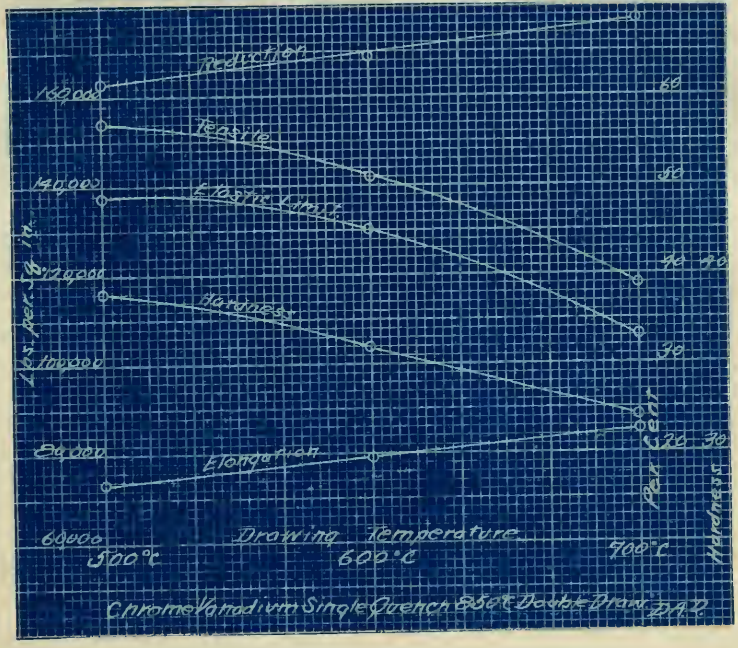
No. 5

NICKEL CHROME VANADIUM
Single Quench 850 C Double Draw



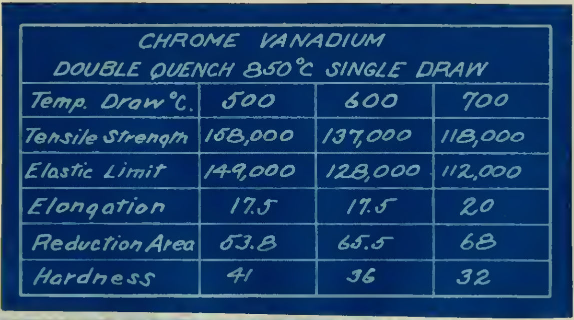
CHROME VANADIUM
SINGLE QUENCH 850°C. DOUBLE DRAW.

Temp. Draw. °C	500	600	700
Tensile Strength	154,000	142,000	118,000
Elastic Limit	137,000	130,000	106,000
Elongation	16.5	19.5	22.5
Reduction Area	61.5	64.7	68.7
Hardness	39	36	32



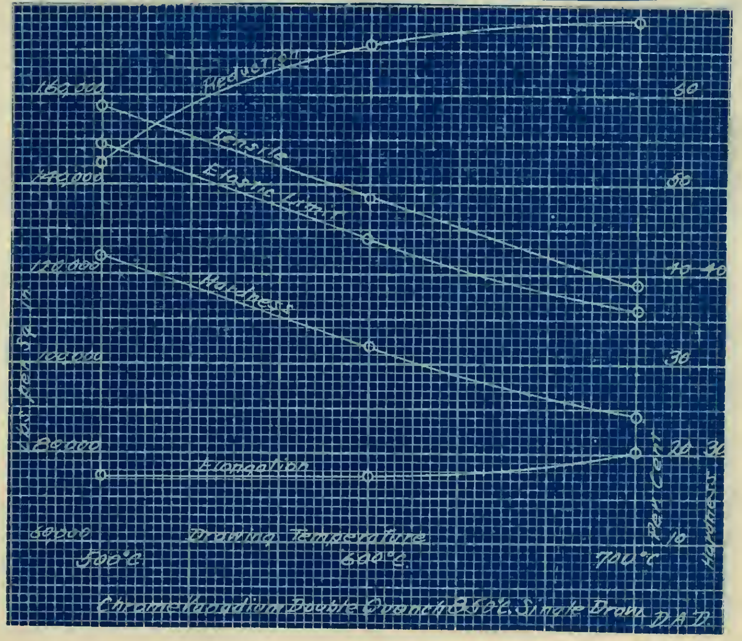
No. 6

NICKEL CHROME VANADIUM
Double Quench 850 C Single Draw



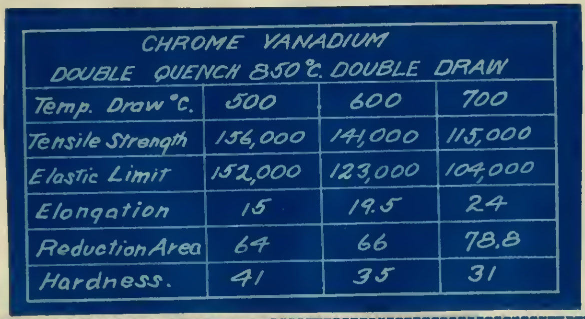
CHROME VANADIUM
DOUBLE QUENCH 850°C SINGLE DRAW

Temp. Draw °C.	500	600	700
Tensile Strength	168,000	137,000	118,000
Elastic Limit	149,000	128,000	112,000
Elongation	17.5	17.5	20
Reduction Area	53.8	65.5	68
Hardness	41	36	32



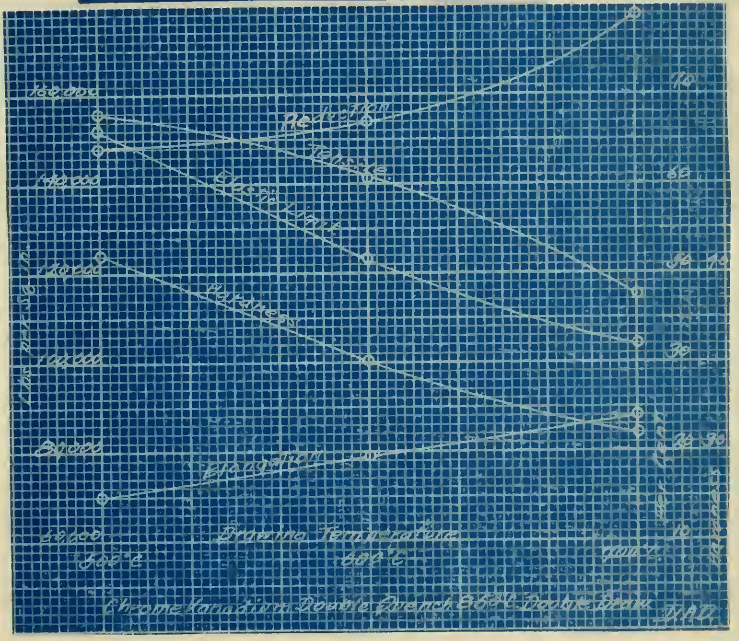
No 7

NICKEL CHROME VANADIUM
Double Quench 850 C Double Draw

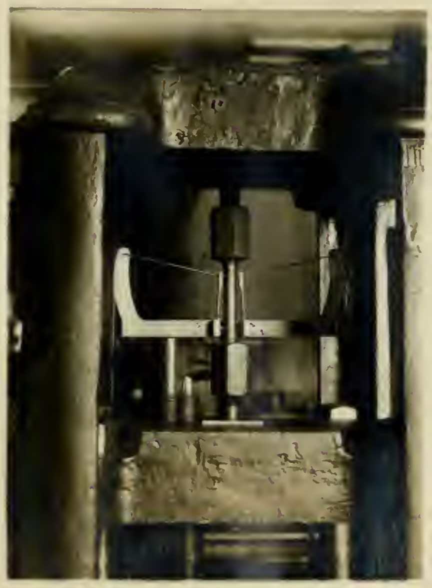


CHROME VANADIUM
DOUBLE QUENCH 850°C. DOUBLE DRAW

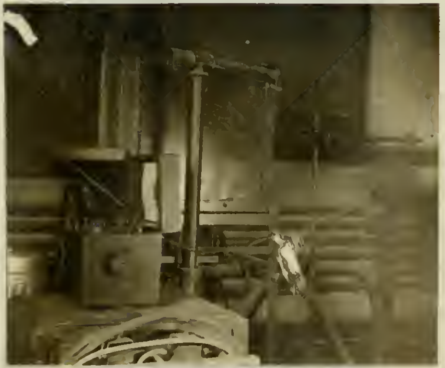
Temp. Draw °C.	500	600	700
Tensile Strength	156,000	141,000	115,000
Elastic Limit	152,000	123,000	104,000
Elongation	15	19.5	24
Reduction Area	64	66	78.8
Hardness.	41	35	31



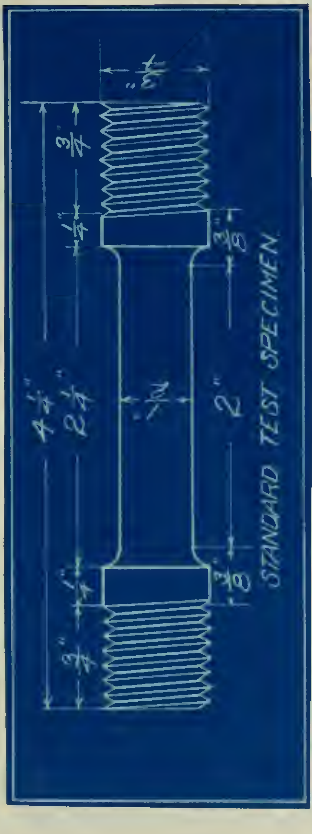
THE EXTENSOMETER



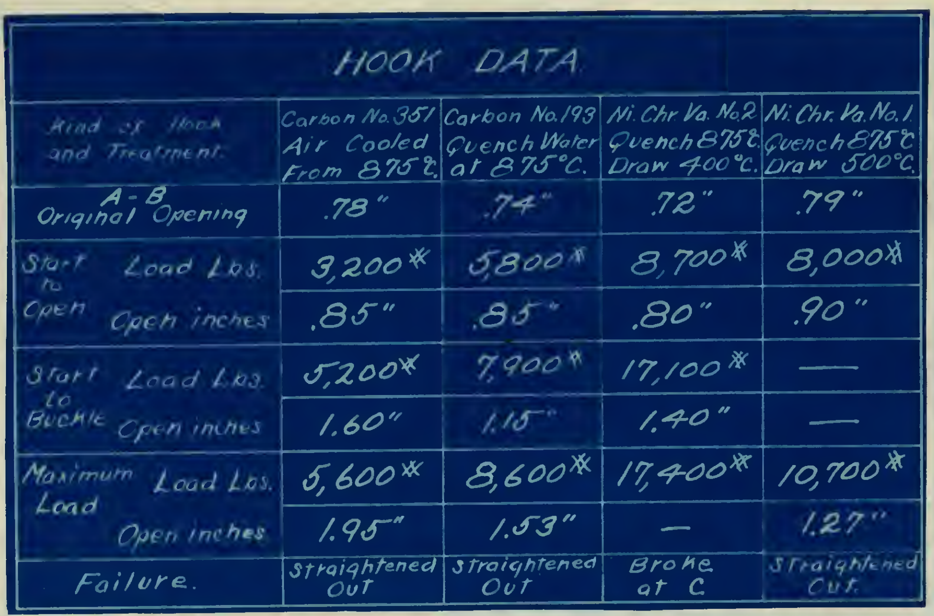
ELECTRIC FURNACE



TEST SPECIMEN

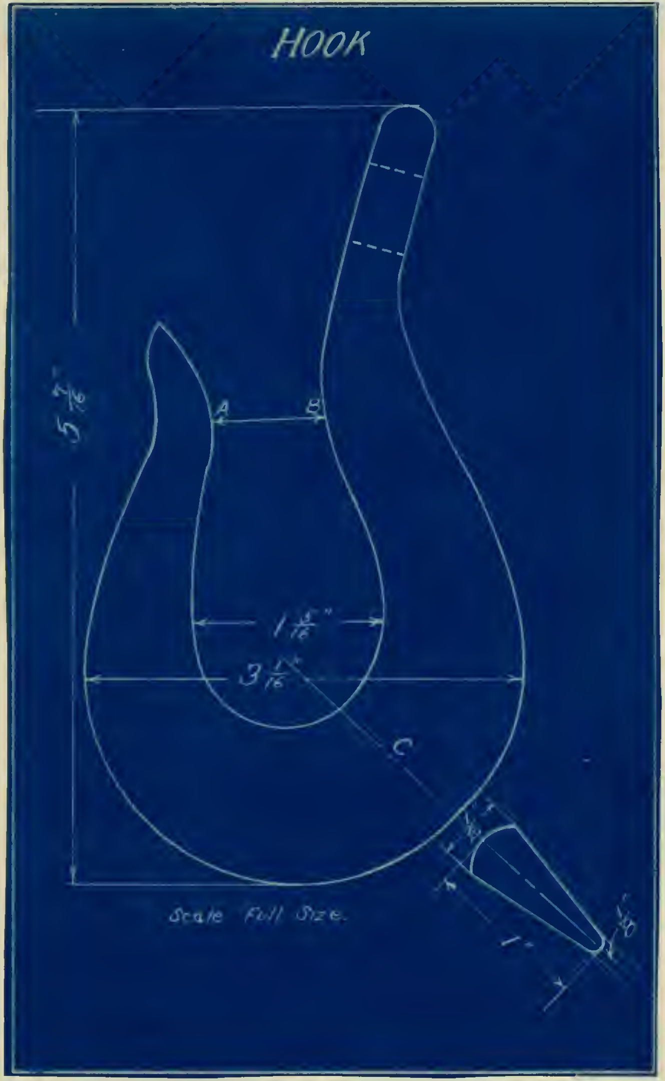


HOOK DATA



HOOK DATA

Kind of Hook and Treatment.		Carbon No. 351 Air Cooled From 875°C.	Carbon No. 193 Quench Water at 875°C.	Ni. Chr. Va. No. 2 Quench 875°C. Draw 400°C.	Ni. Chr. Va. No. 1. Quench 875°C. Draw 500°C.
A - B Original Opening		.78"	.74"	.72"	.79"
Start to Open	Load Lbs.	3,200*	5800*	8,700*	8,000*
	Open inches	.85"	.85"	.80"	.90"
Start to Buckle	Load Lbs.	5,200*	7,900*	17,100*	—
	Open inches	1.60"	1.15"	1.40"	—
Maximum Load	Load Lbs.	5,600*	8,600*	17,400*	10,700*
	Open inches	1.95"	1.53"	—	1.27"
Failure.		Straightened Out	Straightened Out	Broke at C	Straightened Out.


HOOK
5 7/16"
A
B
1 5/16"
3 1/16"
C
1/2"
1"
1/8"
Scale Full Size.

The analysis of specimens Nos. 9, 10, 11, & 12 is as follows :

Carbon	.23 %
Nickel	4.30 %
Chromium	.20 %
Vanadium	.026%
Tungsten	.00 %

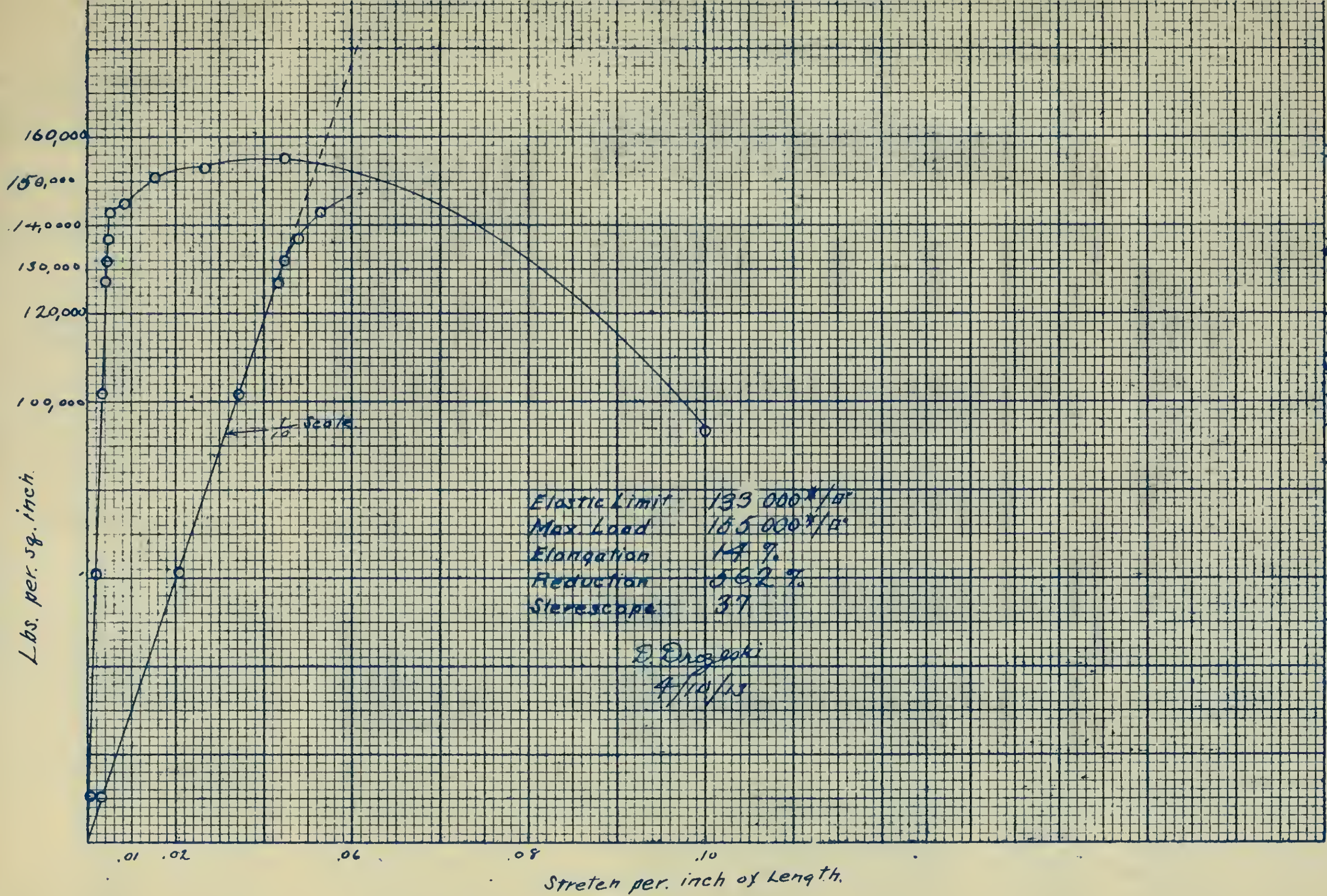
Specimen No. 9.

.30-.40-Carbon
Quench 875 C Draw 400 C.

Load Lbs.		Extensometer ins.			
Actual	Sq. in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0000	.0012	.0006	.0003
4000		.0002	.0022	.0012	.0006
6000		.0009	.0031	.0020	.0010
8000		.0014	.0040	.0027	.00135
10000		.0021	.0046	.0033	.00165
12000	61200	.0029	.0053	.0041	.00205
14000		.0034	.0060	.0047	.00253
16000		.0041	.0069	.0055	.00275
18000		.0050	.0073	.0062	.0031
20000	102000	.0058	.0080	.0069	.00345
21000		.0061	.0082	.0072	.0036
22000		.0065	.0087	.0076	.0038
23000		.0070	.0090	.0080	.0040
24000		.0072	.0093	.0082	.0042
25000	127000	.0076	.0098	.0087	.00435
26000	132000	.0080	.0100	.0090	.0045
27000	137000	.0083	.0109	.0096	.0048
28000	143000	.0090	.0123	.0106	.0053
28500	145000	.0148	.0180	.0164	.0082
29600	151000	.0290	.0320	.0305	.01525
30000	153000	.0515	.0538	.0526	.0263
30400	155000	.		.09	.045
18400	93800	Broke			

Fracture 3/4 cup	
Structure silky	
Elongation per cent	14
Original diam. inches	.500
Final diam. inches	.329
Reduction of area per cent	56.2
Elastic limit lbs. per sq. in.	132000
Max. load lbs. per sq. in.	155000
Modulus of elasticity	29500000
Sclerescope	37

No. 9 .30-40 Carbon Q 875°C D. 400°C.



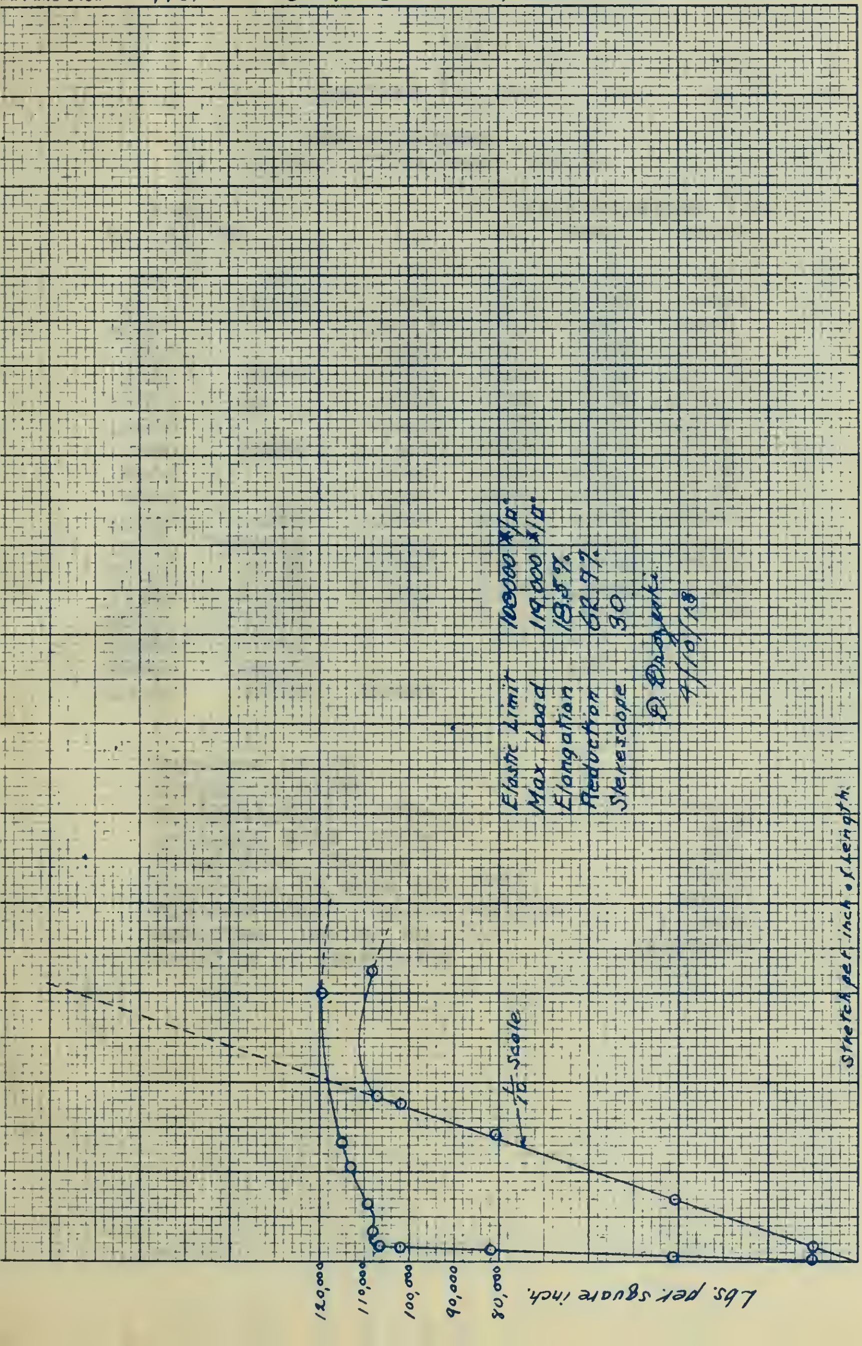
Specimen No. 10.

.30-.40 Carbon
Quench 875 C Draw 500 C.

Load lbs.		Extensiometer ins.			
Actual	Sq. in.	L.	R.	Mean	Per.in.
0	0	0	0	0	0
2000	10200	.0005	.0010	.0007	.00035
4000		.0011	.0019	.0015	.00075
6000		.0019	.0026	.0022	.0011
8000	41000	.0024	.0032	.0028	.0014
10000		.0031	.0040	.0035	.00175
12000		.0039	.0048	.0043	.00215
14000		.0048	.0053	.0050	.0025
16000	82000	.0053	.0061	.0057	.00285
17000		.0059	.0063	.0061	.00305
18000		.0061	.0068	.0064	.0032
19000		.0066	.0070	.0068	.0034
20000	102000	.0070	.0072	.0071	.00355
21000	107000	.0072	.0076	.0074	.0037
21100	108000	.0130	.0130	.0130	.0065
21400	109500	.0256	.0259	.0257	.01285
22100	113000	.0431	.0428	.0429	.02145
22400	114500	.0536	.0530	.0533	.02665
23200	119000			.12	.06

Fracture point cup	
Structure silky	
Elongation per.cent	18.5
Original diam. inches	.499
Final diam. inches	.305
Reduction area per.cent	62.7
Elastic limit lbs.per sq.in.	108000
Max.load lbs.per sq.in.	119000
Modulus of elasticity	29000000

No. 10 .30-.40 Carbon Q 875°C D. 500°C.



Specimen No. 11.

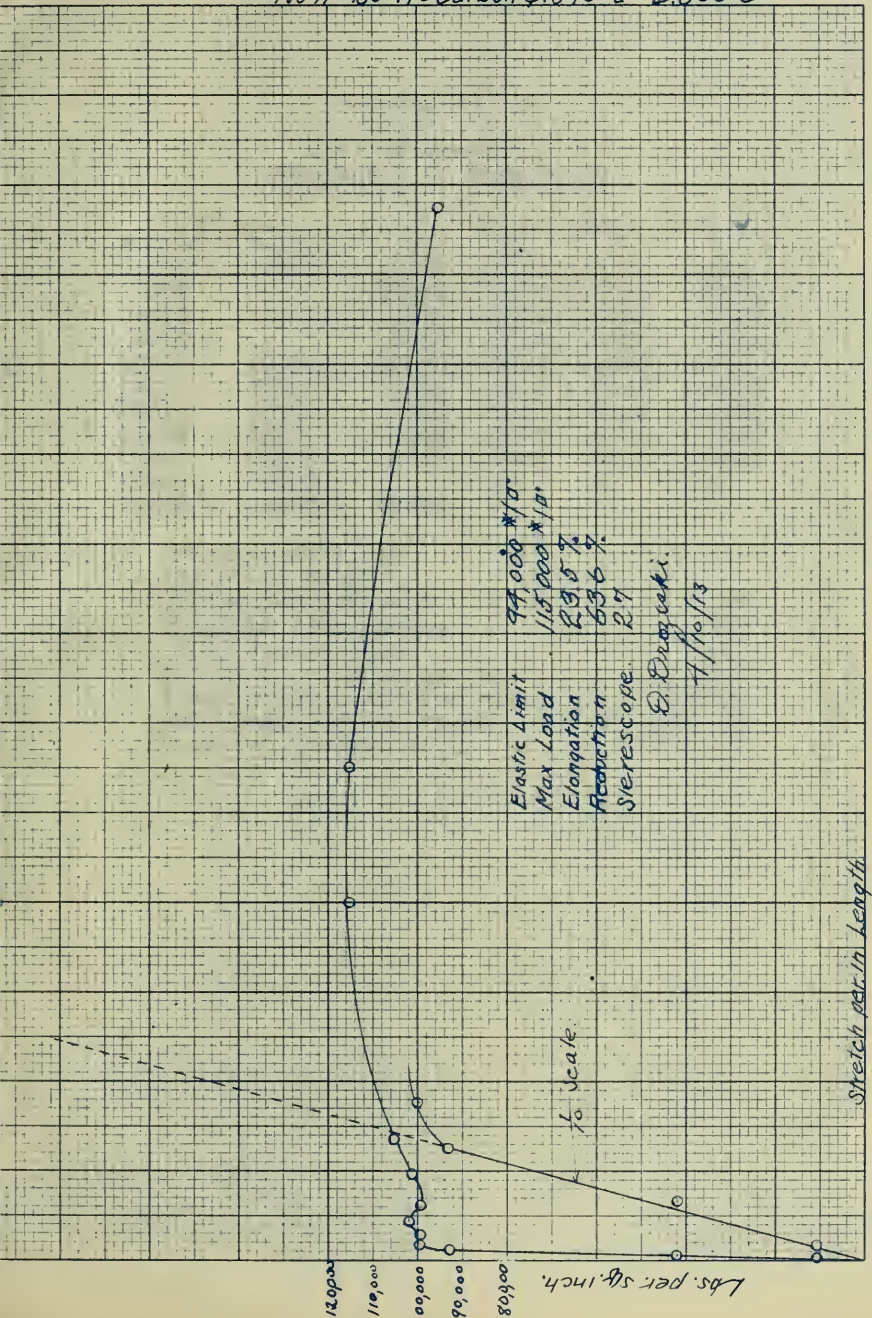
.30-.40 Carbon
Quench 875 C Draw 600 C.

Load lbs.		Extensiometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10500	.0009	.0004	.0007	.00035
4000		.0017	.0010	.0014	.0007
6000		.0024	.0017	.0020	.0010
8000	42000	.0032	.0022	.0027	.00135
10000	.00	.0040	.0029	.0034	.0017
12000		.0050	.0035	.0042	.0021
14000	93500	.0058	.0042	.0050	.0025
16000		.0066	.0049	.0057	.00285
18000		.0073	.0054	.0063	.00315
19000	99500	;0084	.0058	.0071	.00355
19500	102000	.0190	.0154	.0172	.0086
19000	99500	.0268	.0225	.0248	.0124
19400	101800	.0422	.0364	.0393	.01965
20100	105000	.0578	.0512	.0545	.02725
22000	115000			.16	.08
22000	115000			.22	.11
14400	95500	Broke			

Fracture point	
Structure silky	
Elongation per cent.	23.5
Original diam inches	.493
Final diam. inches	.298
Reduction of area per cent.	63.6
Elastic limit lbs.per sq.in.	94400
Max.load lbs.per sq. in.	115000
Modulus of elasticity	36400000

EMAN AND SNOW

No 11 .30-40 Carbon Q.875°C D.600°C



Specimen No. 12.

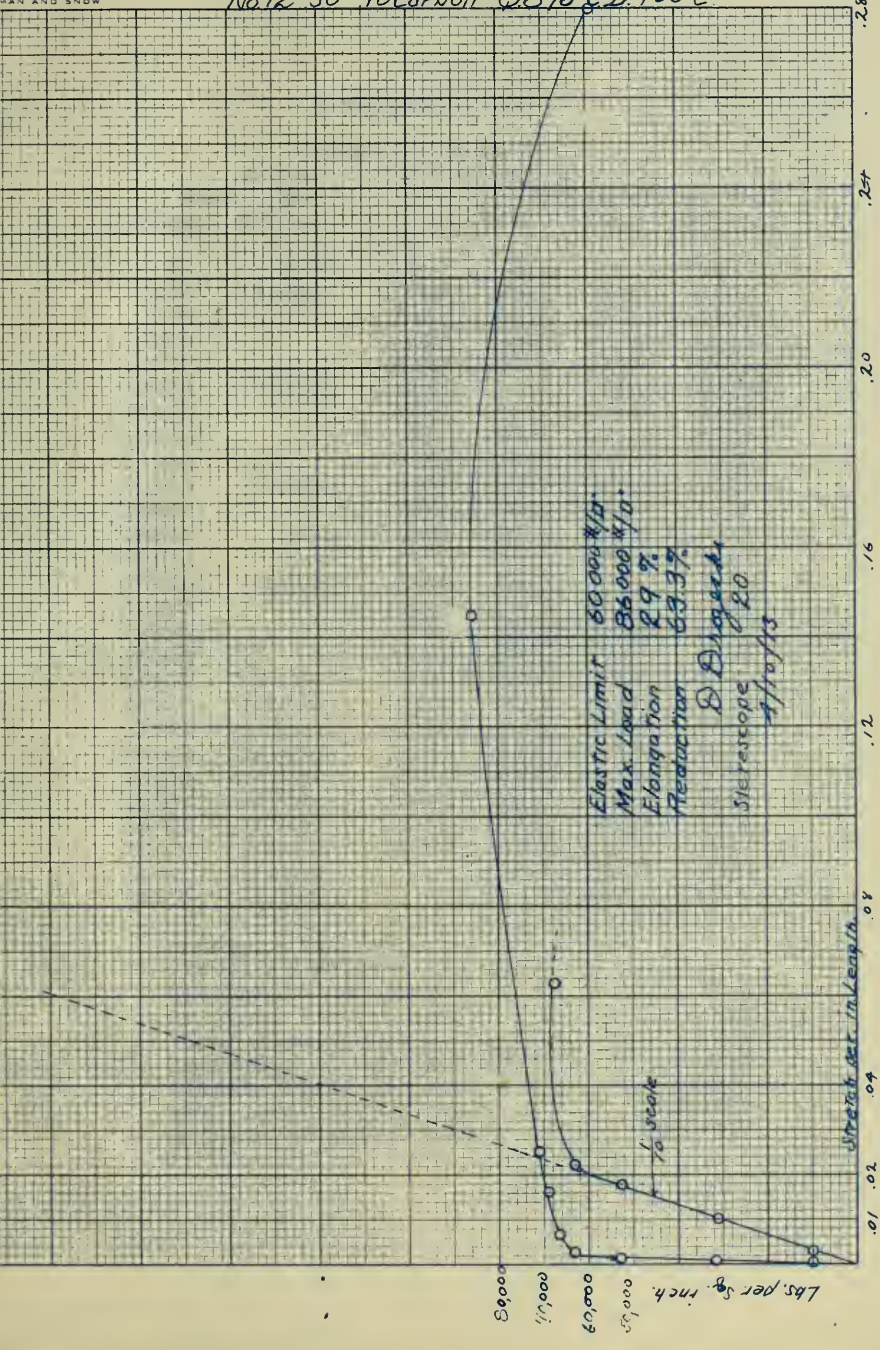
.30-.40 Carbon
Quench 875 C Draw 700 C

Load lbs.		Extensiometer ins.			
Actual	Sq.in.	0	0	0	0
2000	10500	.0010	.0002	.0006	.0003
4000		.0020	.0010	.0015	.00075
6000	31500	.0030	.0012	.0021	.00106
8000		.0038	.0020	.0029	.00145
10000	52700	.0048	.0024	.0036	.0018
12000	63200	.0058	.0032	.0045	.00225
12600	66300	.0150	.0100	.0125	.00625
13000	68500	.0352	.0298	.0325	.01625
13500	71000	.0528	.0482	.0505	.02525
16350	86000		.29	.29	.145
11150	58600	Broke			

Fracture full cup
Structure silky

Elongation per cent	29
Original diam.inches	.492
Final diam.inches	.298
Reduction of area per cent.	63.3
Elastic limit lbs.per sq.in.	60000#
Max. load lbs.per sq.in.	86000#
Modulus of elasticity	29500000#

No 12 30-40 Carbon Q875°C D 700°C



Elastic Limit 80 000 #/□
Max. Load 86 000 #/□
Elongation 29 %
Reduction 63.3%
D Diggett
Slerescope 20
7/10/13

Specimen No. 13.

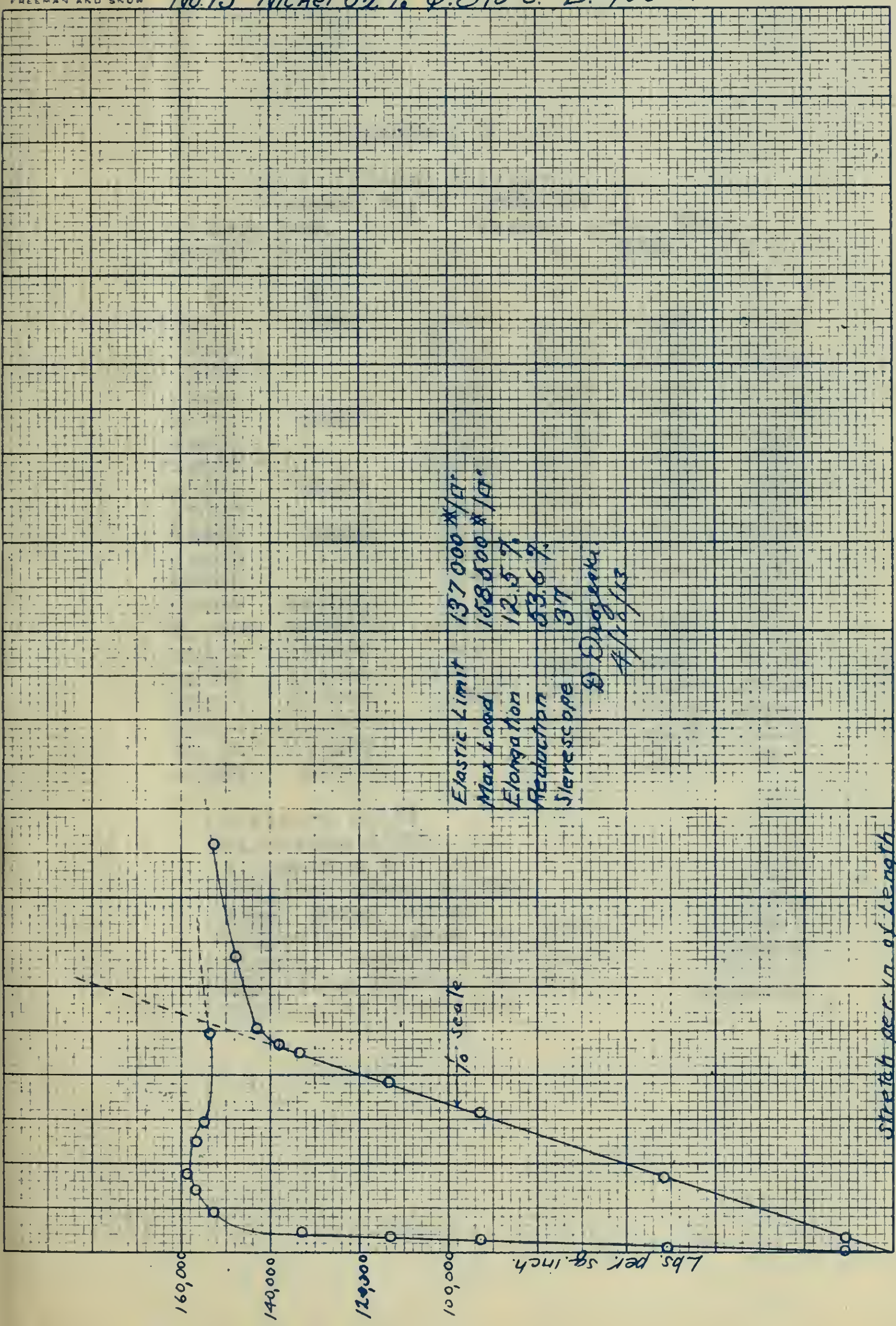
Nickel 3 1/2 %.
Quench 875 C Draw 400 C.

Load Lbs.		Extensiometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per.in.
0	0	0	0	0	0
2000	10200	.0006	.0007	.0006	.0003
4000		.0013	.0012	.0012	.0006
6000		.0020	.0020	.0020	.0010
8000		.0028	.0028	.0028	.0014
10000	51200	.0034	.0033	.0033	.00165
12000		.0041	.0040	.0040	.0020
14000		.0051	.0048	.0050	.0025
16000		.0059	.0053	.0056	.0028
18000	92200	.0068	.0060	.0064	.0032
19000		.0070	.0063	.0066	.0033
20000		.0073	.0068	.0070	.0035
21000		.0078	.0071	.0074	.0037
22000	112600	.0080	.0073	.0077	.00385
23000		.0083	.0076	.0080	.0040
24000		.0088	.0079	.0085	.00425
25000		.0091	.0082	.0086	.0043
26000	133000	.0096	.0086	.0091	.00455
27000	138000	.0100	.0090	.0095	.00475
28000	143000	.0109	.0094	.0102	.0051
29000	148000	.0140	.0128	.0134	.0067
30000	153000	.0190	.0178	.0134	.0067
30800	157000	.0292	.0276	.0284	.0142
31000	158500	.0380	.0350	.0360	.0180
30600	156500	.0525	.0500	.0512	.0256
30400	155500		.0590	.0590	.0295
30100	154000			.10	.05

Fracture full cup	
Structure silky	
Elongation per cent	12.5
Original diam.inches	.499
Final diam.inches	.340
Reduction of area per cent	53.6
Elastic limit lbs.per sq.in.	137000
Max. load lbs.per sq.in.	158500
Modulus of elasticity	29500000

FREEMAN AND SNOW

No. 13 Nickel 3½% Q. 875°C. D. 400°C.



Elastic Limit 137000 #/□"
Max Load 158500 #/□"
Elongation 12.5 %
Reduction 53.6 %
Sclerescope 37

D Dagett
4/16/13

Specimen No. 14.

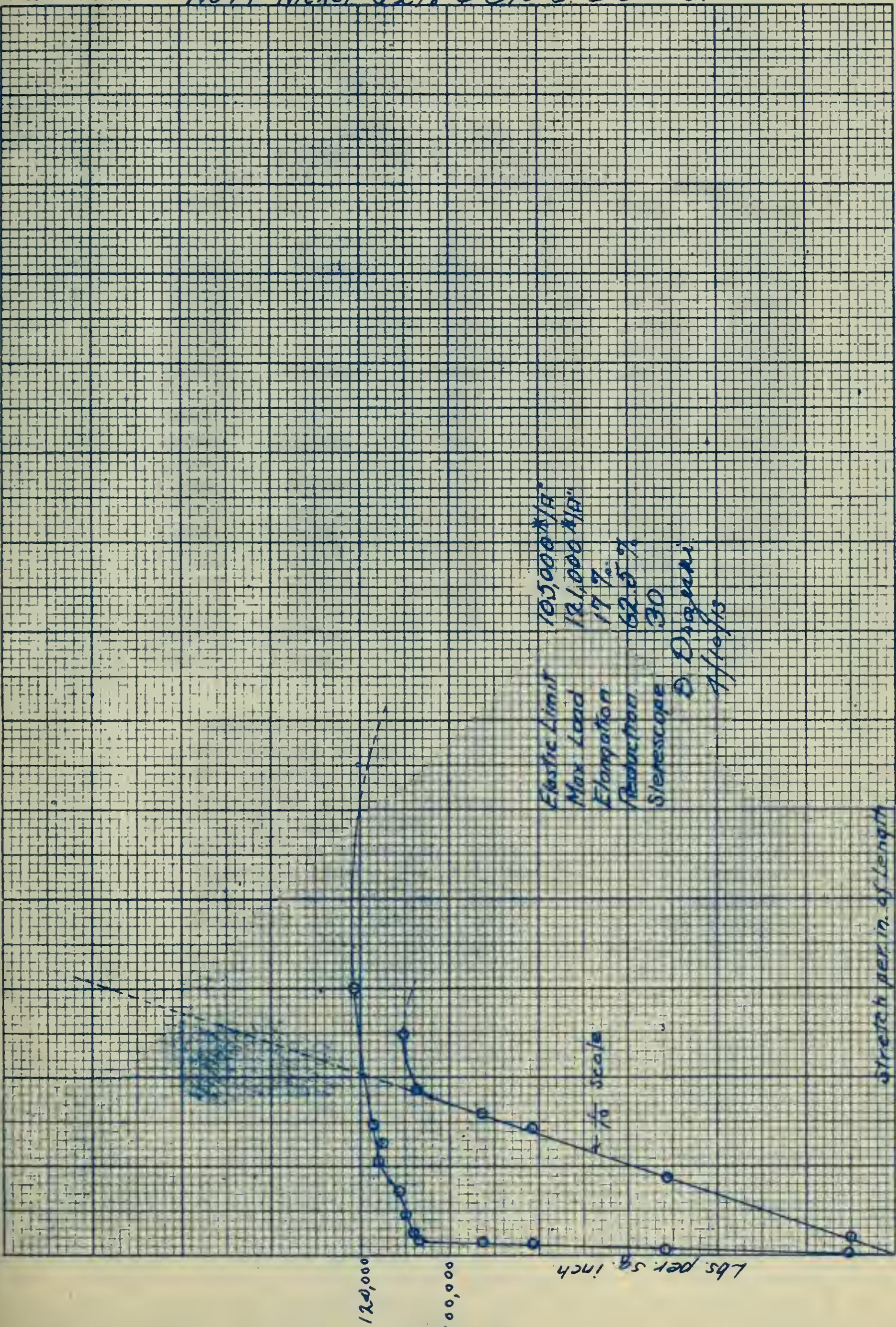
Nickel 3 1/2%
Quench 875 C Draw 500 C.

Load Lbs. Actual	Sq.in.	Extensiometer ins. L.	R.	Mean	Per.in.
0	0	0	0	0	0
2000	10200	.0008	.0010	.0009	.00045
4000		.0012	.0018	.0015	.00075
6000		.0020	.0023	.0021	.00105
8000		.0027	.0031	.0029	.00145
10000	51200	.0031	.0039	.0035	.00175
12000		.0040	.0046	.0043	.00215
14000		.0048	.0052	.0050	.0025
16000	81900	.0054	.0061	.0057	.00285
17000		.0059	.0063	.0061	.00305
18000	92200	.0061	.0068	.0064	.0032
19000		.0062	.0071	.0066	.0033
20000		.0068	.0073	.0070	.0035
21000	107000	.0071	.0079	.0075	.00375
211500	108000	.0095	.0106	.0100	.0050
21500	110000	.0180	.0191	.0185	.00925
21800	111500	.0285	.0293	.0289	.01445
22600	116000	.0420	.0430	.0425	.02125
22500	115000		.0512	.0512	.0256
22700	116200		.0584	.0584	.0292
23700	121000			.12	.06

Fracture point	
Structure silky	
Elongation per cent	17
Original diam. inches	.499
Final diam. inches	.306
Reduction of area per cent	62.5
Elastic limit lbs.per sq.in.	105000
Max. load lbs.Per sq. in.	121000
Modulus of elasticity	29500000

FREEMAN AND SNOW

No 14 Nickel 3½% Q 875°C. D 500°C.



Elastic Limit 105,000 #/□"
Max Load 121,000 #/□"
Elongation 17 %
Reduction 62.5 %
Sleroscope 30
D. Dagenais
4/10/13

Specimen No. 15.

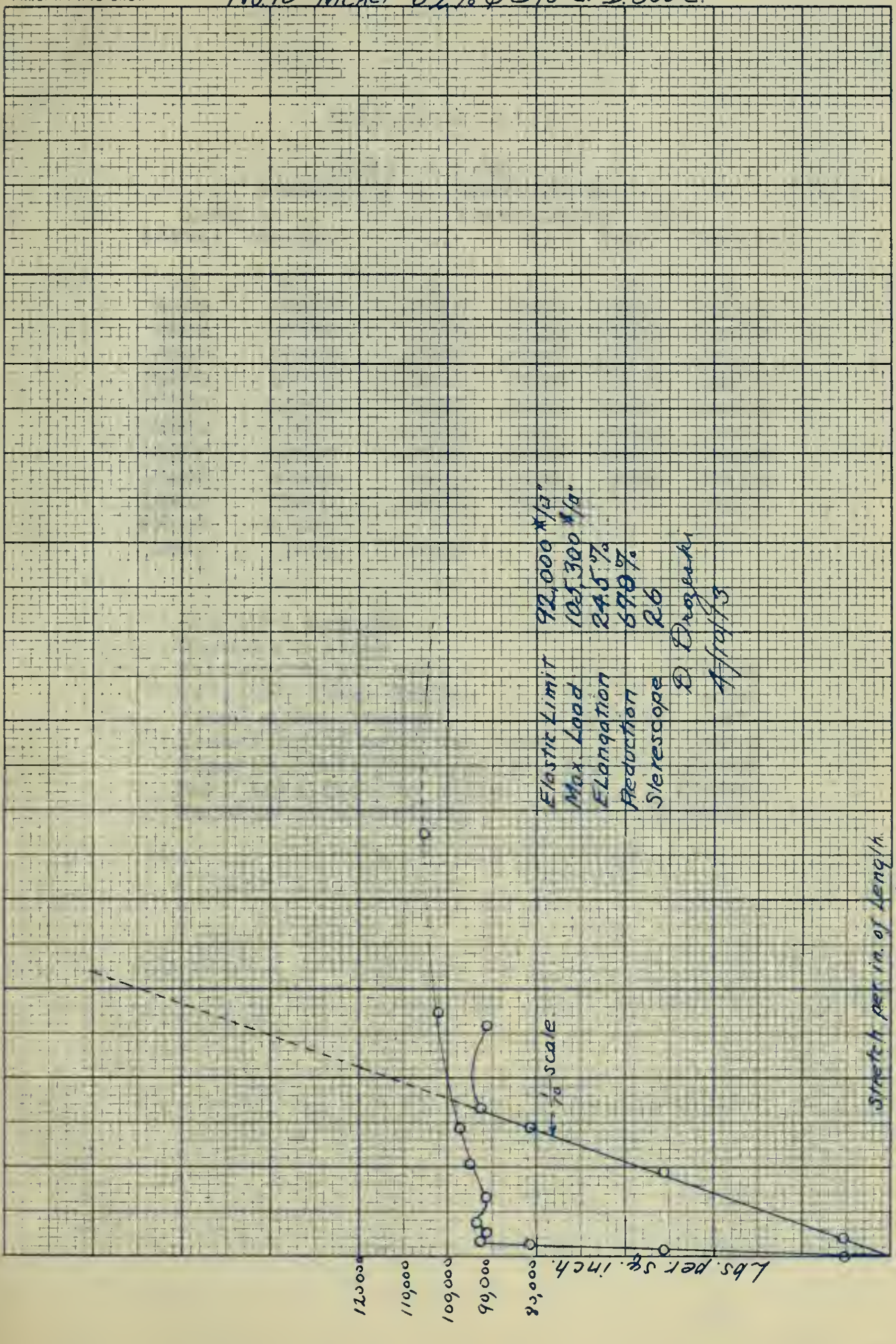
Nickel 3 1/2 %
Quench 875 C Draw 600 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per.in.
0	0	0	0	0 0	0
2000	10200	.0001	.0016	.0008	.0004
4000		.0010	.0023	.0016	.0008
6000		.0016	.0031	.0023	.00115
8000		.0022	.0039	.0030	.0015
10000	51200	.0030	.0046	.0038	.0019
12000		.0038	.0051	.0044	.0022
14000		.0043	.0060	.0051	.00255
16000	81900	.0051	.0068	.0058	.0029
17000		.0057	.0070	.0063	.00315
18000	92200	.0060	.0072	.0066	.0033
17700	90600	.0090	.0120	.0105	.00525
18300	93500	.0150	.0162	.0156	.0078
17900	91600	.0268	.0277	.0272	.0136
18500	94600	.0400	.0412	.0406	.0203
19100	97500	.0570	.0580	.0575	.02875
20000	102000			.11	.055
20500	105300			.19	.095

Fracture point	
Structure silky	
Elongation per cent	24.5
Original diam. inches	.499
Final diam. inches	.284
Reduction area per cent	67.8
Elastic limit lbs.per sq.in.	92100
Max. load lbs. per sq.in.	105000
Modulus of elasticity	28100000

FREEMAN AND SNOW

No. 15 Nickel 3½% Q875°C. D600°C.



Elastic Limit 92,000 #/□"
Max Load 105,300 #/□"
Elongation 24.5 %
Reduction 69.9 %
Sleresdope 26
D Drozeski
4/10/13

Specimen No. 16.

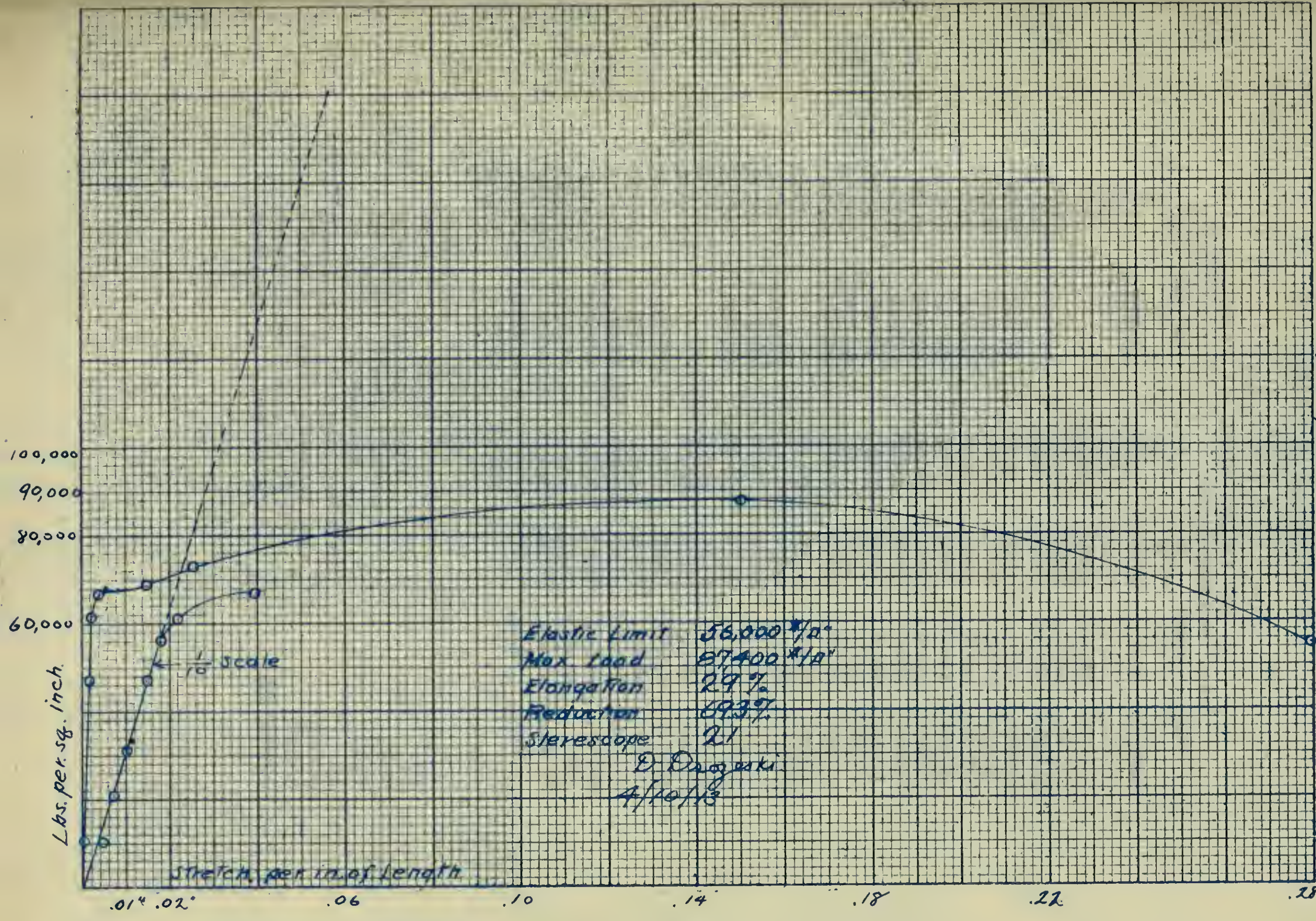
Nickel 3 1/2%

Quench 875 C Draw 700 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per.in.
0	0	0	0	0	0
2000	10200	.0010	.0009	.0010	.0005
4000	20400	.0018	.0012	.0015	.00075
6000	30600	.0023	.0021	.0022	.0011
88000	40700	.0031	.0029	.0030	.0015
10000	56000	.0039	.0033	.0036	.0018
12000	61200	.0048	.0040	.0044	.0022
13000	66200	.0090	.0068	.0079	.00395
13400	68300	.0305	.0281	.0293	.01465
14200	72400	.0528	.0490	.0509	.02545
17150	87400			.30	.15
10600	54000	Broke			

Fracture 3/4 cup	
Structure silky	
Elongation per cent	29
Original diam. inches	.500
Final diam. inches	.277
Reduction of area per cent	69.3
Elastic limit lbs. per sq. in.	56000#
Max. load lbs.per sq.in.	87400#
Modulus of elasticity	31000000

No 16 Nickel 3½% Q 875°C D 700°C.



Elastic Limit	56,000 #/□"
Max Load	87,400 #/□"
Elongation	29%
Reduction	69.9%
Stereoscope	21

D. Dzugaski
4/10/13

Specimen No. 17.

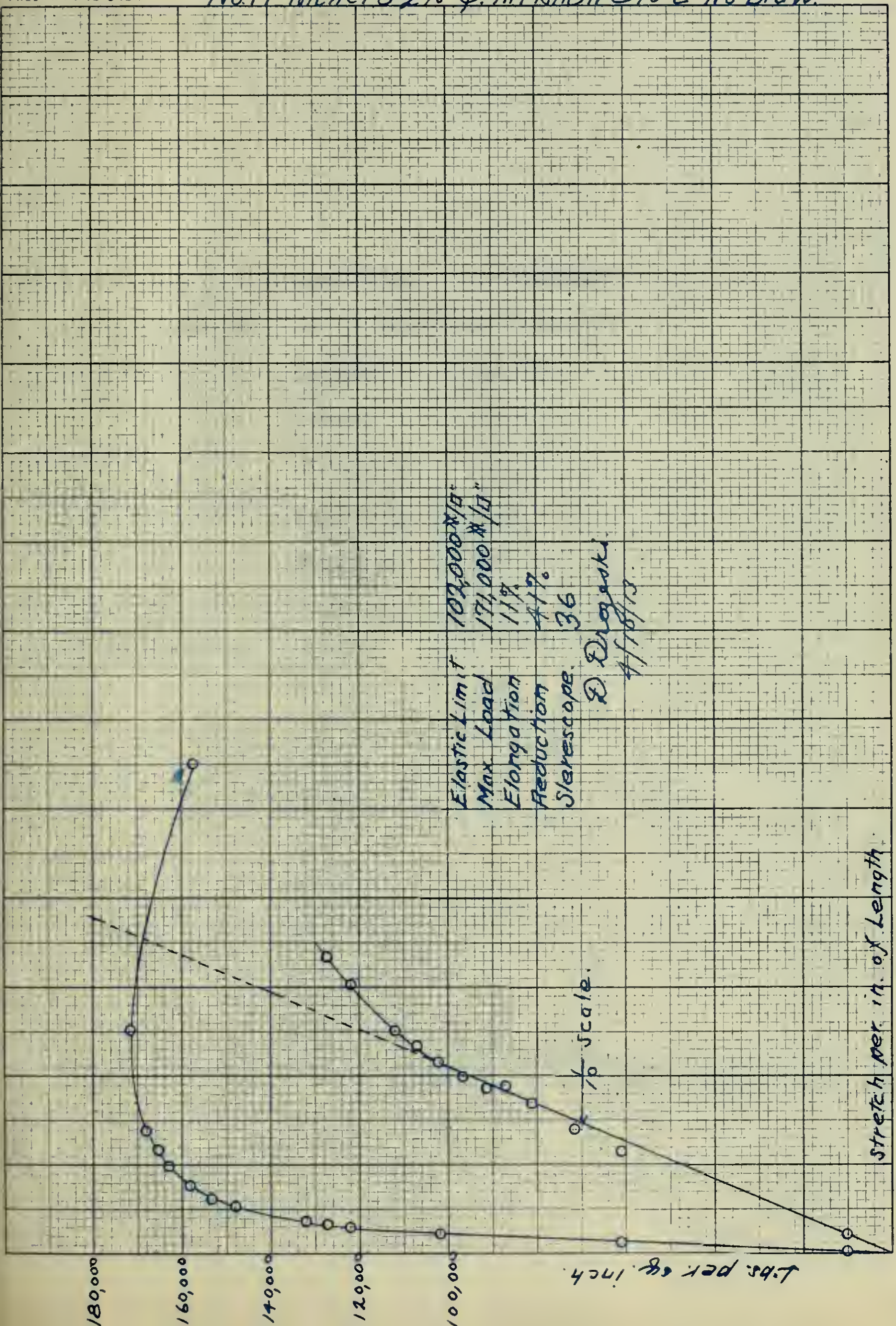
Nickel 3 1/2 %
Quenched in fish oil at 875 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0009	.0009	.0009	.00045
4000		.0014	.0016	.0015	.00075
6000		.0023	.0023	.0023	.00115
8000		.0030	.0031	.0030	.0015
10000		.0038	.0040	.0039	.00195
12000	61200	.0044	.0048	.0046	.0023
14000	71300	.0054	.0058	.0056	.0028
16000	81500	.0062	.0066	.0064	.0032
17000	86600	.0070	.0081	.0076	.0038
18000	91800	.0073	.0076	.0074	.0037
19000	96800	.0080	.0080	.0080	.0040
20000	102000	.0083	.0088	.0086	.0043
21000	107000	.0091	.0096	.0094	.0047
22000	112000	.0100	.0103	.0102	.0051
23000		.0109	.0112	.0110	.0055
24000	122000	.0119	.0123	.0121	.00605
25000	127000	.0130	.0138	.0134	.0067
26000	133000	.0143	.0153	.0148	.0074
27000		.0161	.0171	.0166	.0083
28000		.0182	.0190	.0186	.0093
29000	148000	.0208	.0217	.0212	.0106
30000	153000	.0241	.0250	.0246	.0123
31000	158000	.0308	.0311	.0310	.0155
32000	163000	.0378	.0380	.0379	.01995
32500	165000	.0468	.0468	.0468	.0234
33000	168000	.0560	.0553	.0556	.0278
33500	171000			.10	.05
26900	157000	Broke			

Fracture full cup	
Structure silky	
Elongation per cent	11
Original diam. inches	.500
Final diam. inches	.387
Reduction of area per cent	41
Elastic limit lbs.per sq. in.	102000
Max. load lbs.per sq.in.	171000
Modulus of elasticity	23700000

FREEMAN AND SNOW

No.17 Nickel 3½% Q. in Fish Oil 875°C No Draw.



Elastic Limit 102,000 #/□"
Max Load 171,000 #/□"
Elongation 11%
Reduction 41%
Sleroscope 36
D. Drogoski
4/10/13

The analysis of specimens No. 18, 19, 20, 21, 22, & 25 is as follows:

Carbon	.49 %
Nickel	.00 %
Chromium	.10 %
Vanadium	.013 %
Tungsten	.00 %

Specimen No. 18.

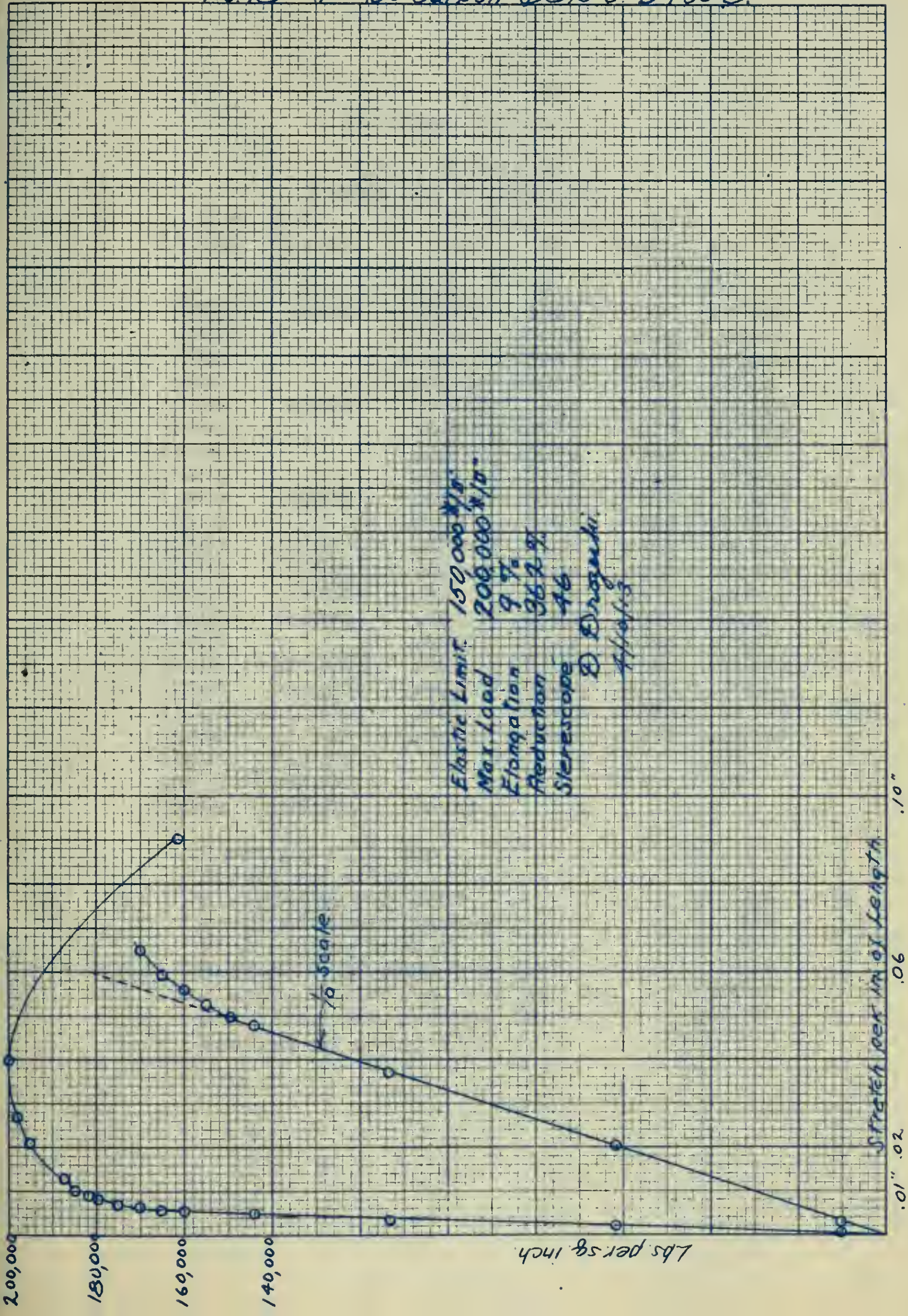
.40-.50 Carbon
Quenched 875 C Draw 400 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10300	.0007	.0005	.0006	.0006
4000		.0011	.0012	.0011	.00055
6000		.0019	.0021	.0020	.0010
8000		.0022	.0030	.0026	.0013
100000		.0030	.0038	.0034	.0017
12000	61900	.0038	.0044	.0041	.00205
14000		.0043	.0051	.0047	.00235
16000		.0050	.0059	.0054	.0027
18000		.0059	.0065	.0063	.0031
20000		.0068	.0072	.0070	.0035
22000	113000	.0072	.0078	.0075	.00375
24000		.0080	.0083	.0082	.0041
25000		.0082	.0088	.0085	.00425
26000		.0088	.0091	.0089	.00445
27000		.0090	.0094	.0092	.0046
28000	144000	.0094	.0098	.0096	.0048
29000	149500	.0100	.0101	.0100	.0050
30000	155000	.0103	.0108	.0106	.0053
31000	160000	.0110	.0113	.0112	.0056
32000	165000	.0118	.0120	.0119	.00595
33000	170000	.0129	.0130	.0130	.0065
34000	175000	.0140	.0140	.0140	.0070
35000	180000	.0170	.0168	.0169	.00845
35200	181000	.0190	.0172	.0181	.00905
36000	185000	.0210	.0192	.0201	.01005
36400	187000	.0268	.0240	.0254	.0127
37800	195000	.0422	.0384	.0403	.02015
38400	198000		.0545	.0545	.02725
38800	200000			.08	.04
31200	161000	Broke			

Fracture full cup
Structure silky

Elongation per cent	9
Original diam. inches	.497
Final diam. inches	.397
Reduction of area per cent	36.2
Elastic limit lbs.per sq.in.	150000
Max. load lbs.per sq.in.	200000
Modulus of elasticity	30000000

No. 18 40-50 Carbon Q875°C. D400°C.



Elastic Limit 150,000 #/□"
Max Load 200,000 #/□"
Elongation 9%
Reduction 36.2%
Stereoscope 46
D Drogeski
4/10/13

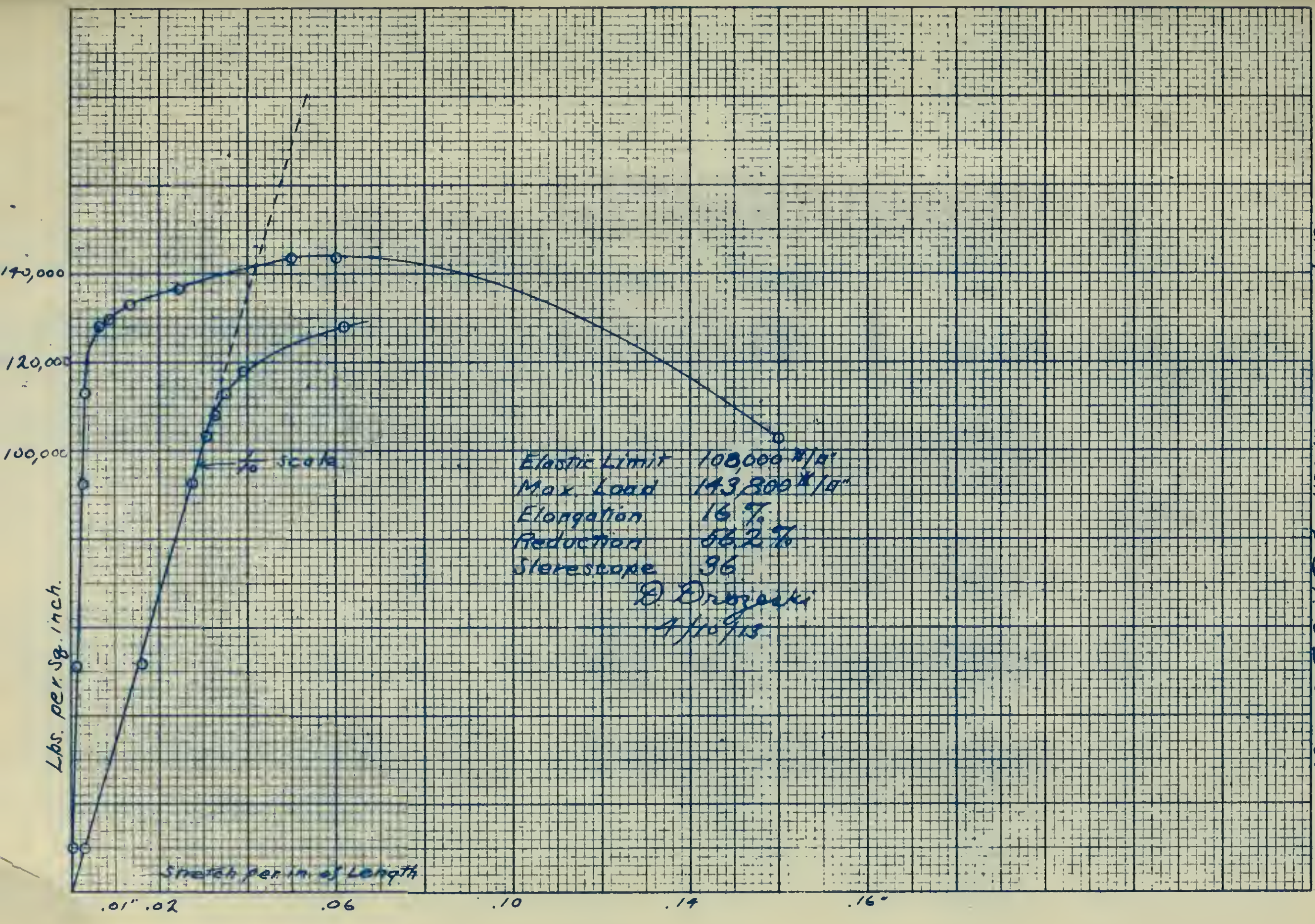
Specimen No. 19.

.40-.50 Carbon
Quench 875 C Draw 500 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	per in.
0	0	0	0	0	0
2000	10260	-.0008	.0020	.0006	.0003
4000		-.0010	.0036	.0013	.00075
6000		-.0010	.0049	.0019	.00095
8000		-.0010	.0058	.0024	.0012
10000	51400	.0000	.0064	.0032	.00160
12000		.0003	.0071	.0037	.00185
14000		.0005	.0079	.0042	.0021
16000		.0011	.0087	.0049	.00245
18000	92400	.0019	.0092	.0055	.00275
19000		.0021	.0098	.0059	.00295
20000	102600	.0023	.0100	.0061	.00305
21000	108000	.0028	.0106	.0067	.00335
22000	113000	.0030	.0112	.0071	.00355
23000	118000	.0032	.0124	.0078	.0039
24000		.0040	.0149	.0094	.0047
25000	128000	.0061	.0190	.0125	.00625
25200	129200	.0111	.0242	.0176	.0088
26000	133500	.0213	.0346	.0279	.01395
26600	136500	.0433	.0549	.0491	.02445
28000	143800			.1	.05
28000	143800			.12	.06
20000	102600	Broke			

Fracture full cup	
Structure silky	
Elongation per cent	16
Original diam. inches	.498
Final diam. inches	.330
Reduction of area per cent	56.2
Elastic limit lbs. per sq. in.	108000
Max. load lbs.per sq. in.	143800
Modulus of elasticity	34000000

No. 19 40-.50 Carbon Q 875°C D 500°C.



Elastic Limit	108,000 #/□"
Max. Load	143,800 #/□"
Elongation	16 %
Reduction	56.2 %
Stereoscope	96

D. Drozdzki
4/10/13

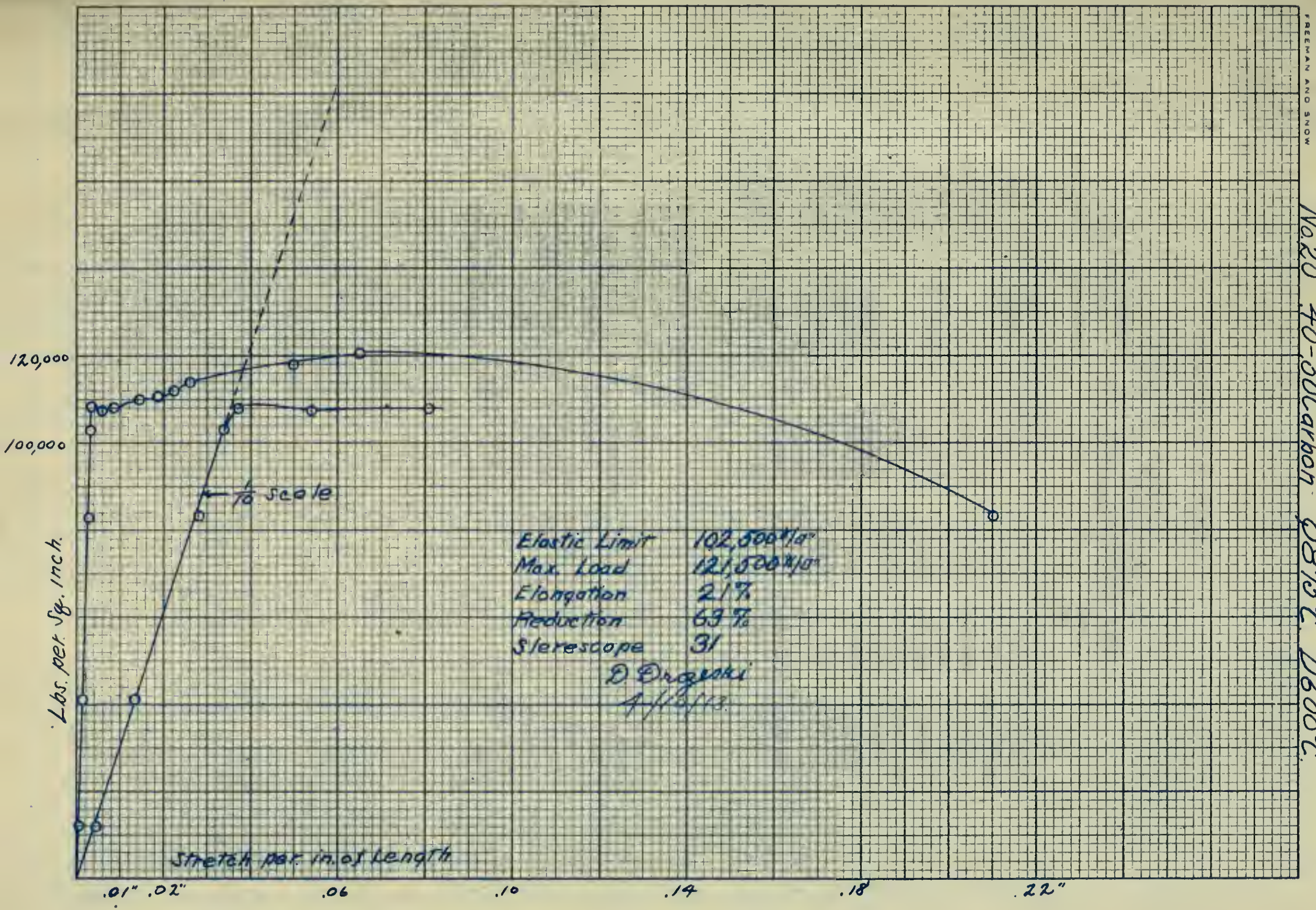
Specimen No. 20.

.40-.50 Carbon
Quench 875 C Draw 600 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10250	.0009	.0009	.0009	.00045
4000		.0013	.0014	.0014	.0007
6000		.0020	.0023	.0021	.00105
8000	41100	.0024	.0031	.0027	.00135
10000		.0030	.0039	.0034	.0017
12000		.0038	.0047	.0042	.0021
14000		.0042	.0052	.0047	.00235
16000	82200	.0051	.0061	.0056	.0028
18000		.0058	.0068	.0063	.00315
19000		.0061	.0071	.0066	.0033
20000	102500	.0064	.0073	.0068	.0034
21000	108000	.0069	.0078	.0074	.0037
20800	106000	.0106	.0110	.0108	.0054
21000	108000	.0159	.0165	.0162	.0081
21400	110000	.0279	.0287	.0283	.01415
21500	110500	.0370	.0381	.0375	.01875
21900	112500	.0438	.0449	.0444	.0222
22170	114000	.0518	.0522	.0520	.0260
23000	118000			.10	.05
23600	121500			.13	.065
16300	83700	Broke			

Fracture point	
Structure silky	
Elongation per cent	21
Original diam. inches	.498
Final diam. inches	.303
Reduction of area per cent	63
Elastic limit lbs.per sq.in.	102500
Max. load lbs.per sq.in.	121500
Modulus of elasticity	30500000
Slerescope	31

No.20 40-50Carbon Q875°C. D600°C.



Elastic Limit 102,500#/□"
Max. Load 121,500#/□"
Elongation 21%
Reduction 63%
Sleresscope 31

D. Drozeski
4/12/13

Specimen No. 21.

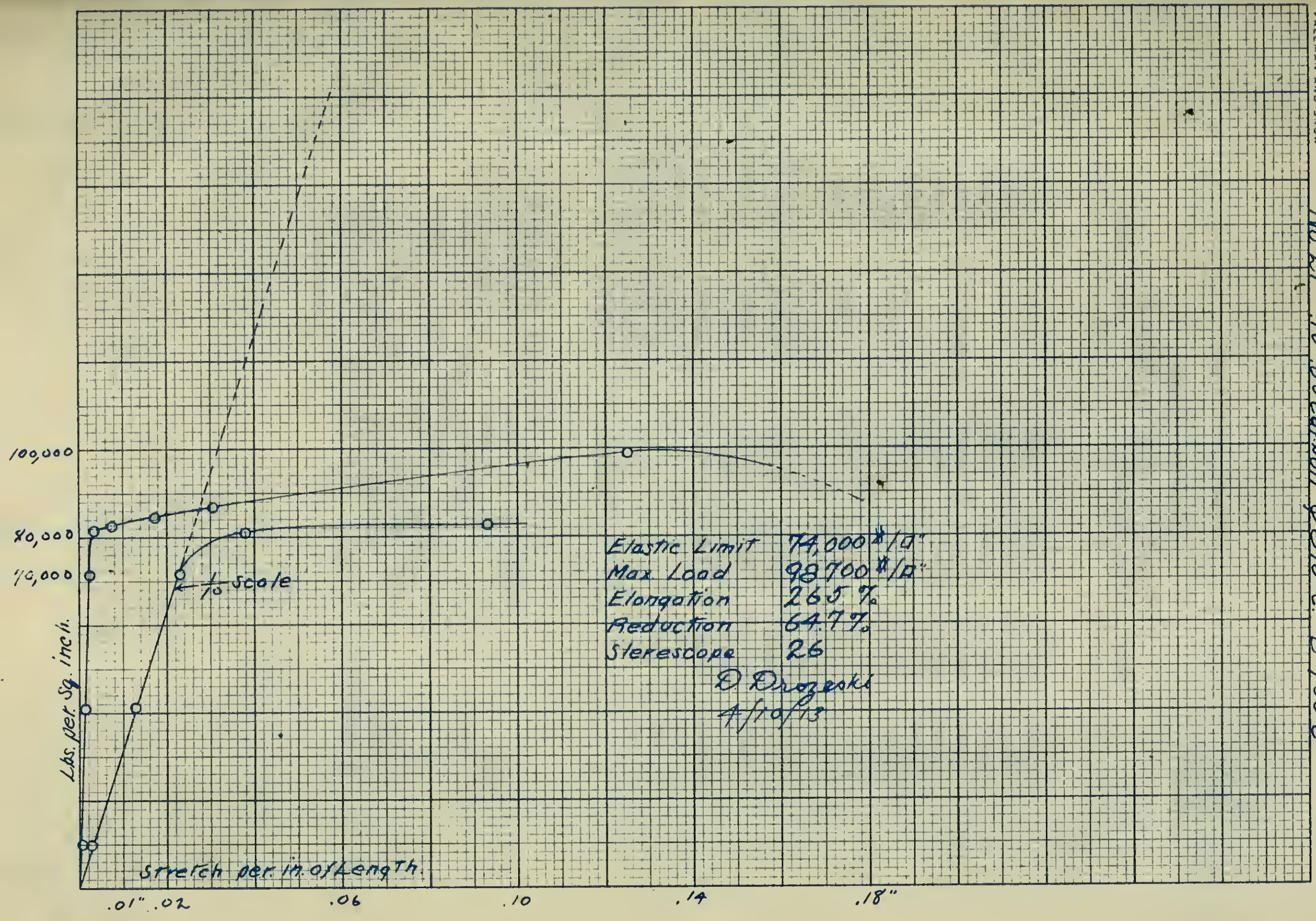
.40-.50 Carbon
Quench 875 C Draw 700 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0011	.0000	.0005	.00025
4000		.0022	.0001	.0011	.00055
6000		.0032	.0008	.0020	.0010
8000	41000	.0040	.0012	.0026	.0013
10000		.0050	.0020	.0035	.00175
12000		.0057	.0025	.0041	.00205
14000	71600	.0062	.0032	.0047	.00235
16000	81800	.0092	.0060	.0076	.0038
16100	82400	.0168	.0124	.0146	.0073
16500	84500	.0360	.0350	.0355	.01775
17000	87400	.0580	.0660	.0620	.0310
19300	98700			.25	.125

Fracture square	
Structure silky	
Elongation per cent	26.5
Original diam. inches	.499
Final diam. inches	.297
Reduction of area per cent	64.7
Elastic limit lbs.per sq.in.	74000
Max. load lbs.per sq.in.	98700
Modulus of elasticity	31300000
Slerescope	26

FREEMAN AND SNOW

No 21 .40-.50 Carbon Q 875°C. D 700°C



Elastic Limit	74,000 #/□"
Max Load	98700 #/□"
Elongation	26.5 %
Reduction	64.7 %
Stereoscope	26

D. Drozeski
4/10/13

Specimen No. 22.

.40-.50 Carbon
Quench 875 C in Fish Oil

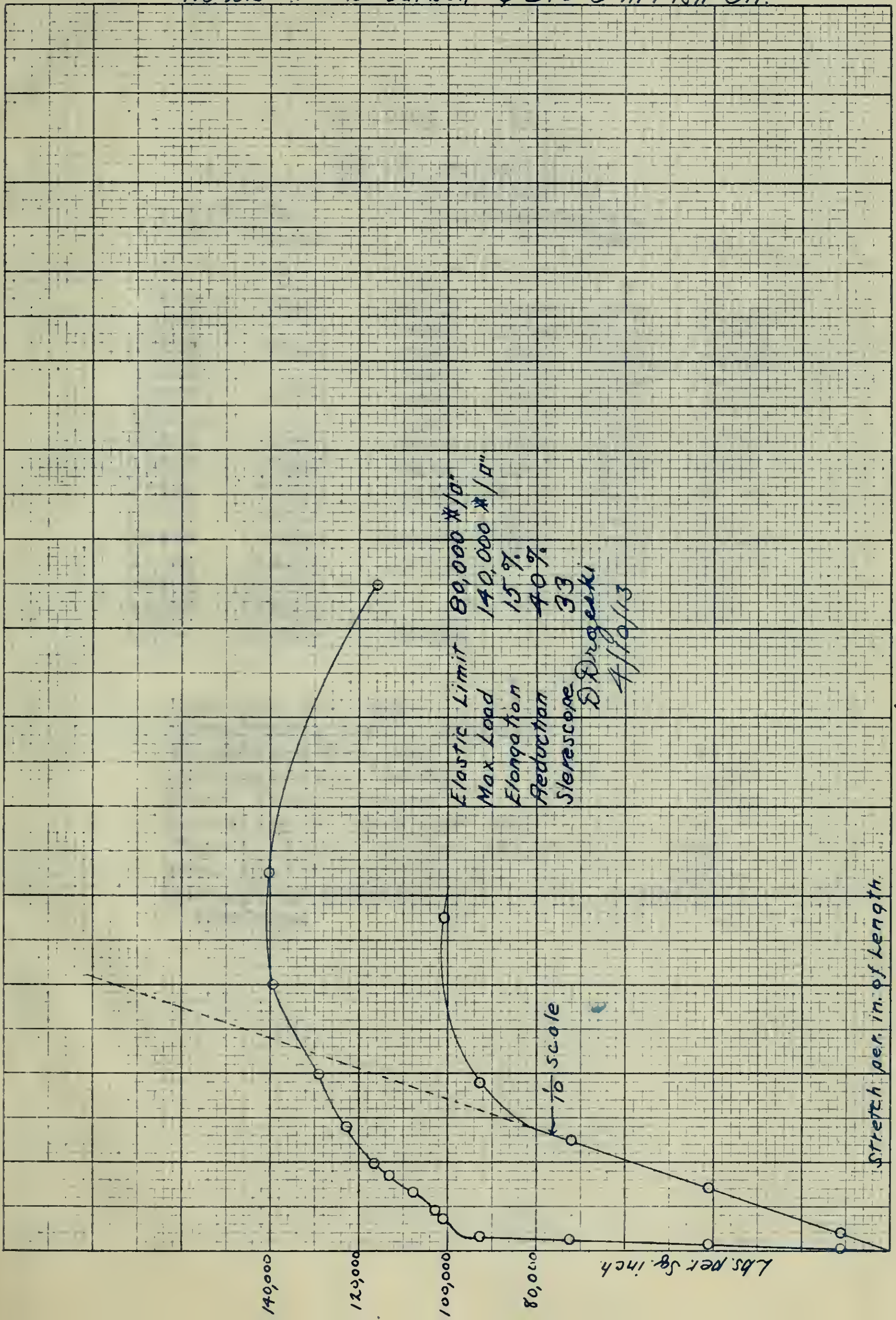
Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10300	.0003	.0012	.0008	.0004
4000		.0010	.0021	.0016	.0008
6000		.0018	.0029	.0024	.0012
8000	41300	.0023	.0033	.0028	.0014
10000		.0030	.0041	.0036	.0018
12000		.0038	.0049	.0044	.0022
14000	72200	.0044	.0056	.0050	.0025
16000		.0053	.0064	.0058	.0029
18000	92800	.0071	.0081	.0076	.0038
19500	100500	.0143	.0157	.0150	.0075
20100	103500	.0178	.0188	.0183	.0092
21100	109000	.0260	.0269	.0264	.0132
22000	113500	.0328	.0335	.0334	.0167
22600	116500	.0398	.0400	.0399	.0199
23750	122500	.0533	.0539	.0536	.0268
25000	129000			.08	.04
27000	139000			.12	.06
27200	140000			.17	.085
22500	116000	Broke			

Fracture full cup
Structure inclined to fibrous

Elongation per cent	15
Original diam. inches	.497
Final diam. inches	.385
Reduction of area per cent	40
Elastic limit lbs.per sq. in.	80000
Max. load lbs. per sq.in.	140000
Modulus of elasticity	29000000
Slerescope	33

FREEMAN AND SNOW

No 22 40-50Carbon Q875°C in Fish Oil.



Specimen No. 25.

.40-.50 Carbon.
Quench 875 C in mineral Oil

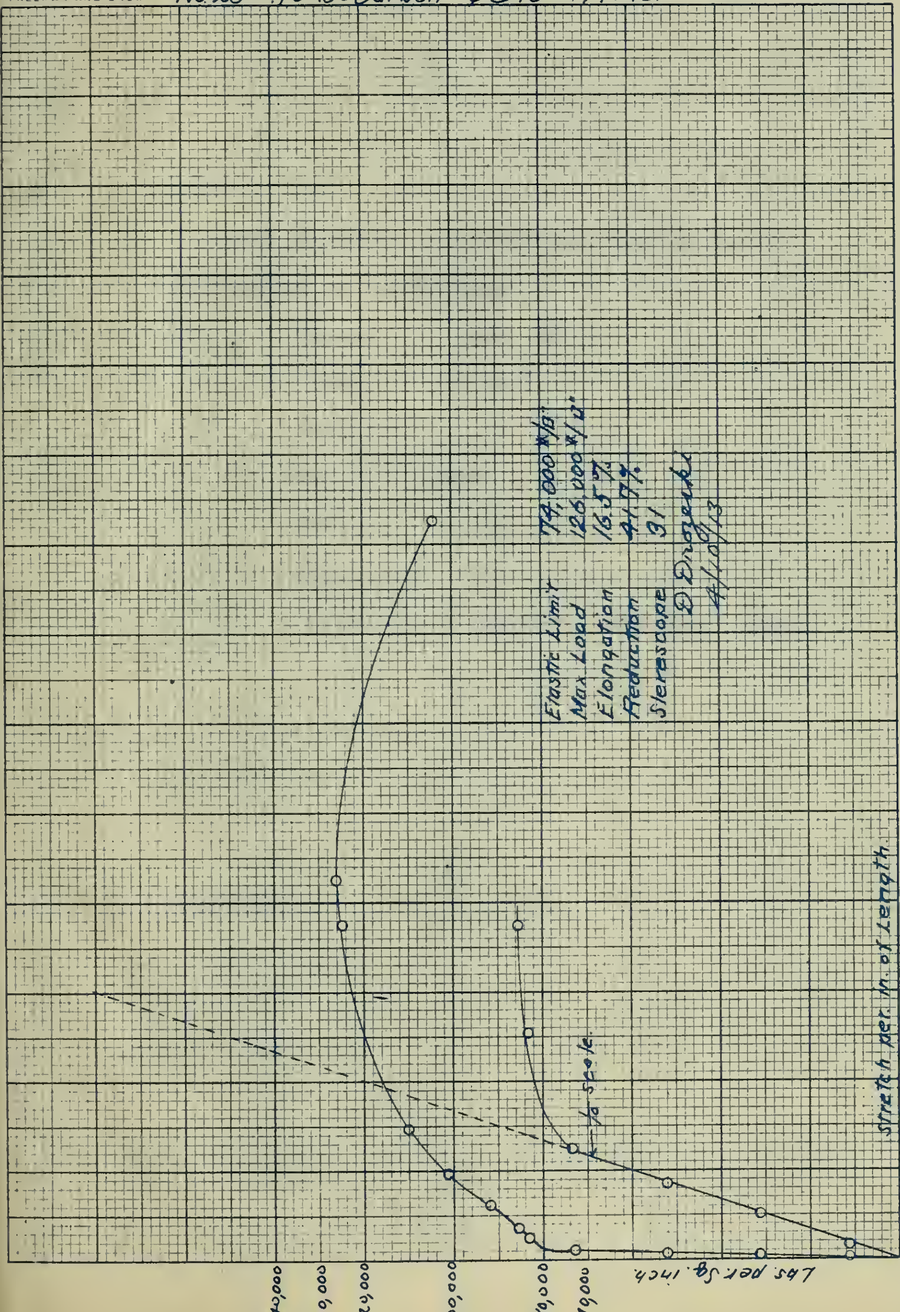
Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10400	.0010	.0003	.0007	.00035
4000		.0020	.0009	.0015	.00075
6000	31200	.0027	.0015	.0021	.00105
8000		.0032	.0022	.0027	.00135
10000	52000	.0040	.0030	.0035	.00175
12000		.0049	.0037	.0043	.00215
14000	72800	.0058	.0042	.0050	.0025
16000	83200	.0112	.0091	.0102	.0051
16350	85000	.0160	.0150	.0155	.00775
17700	92000	.0240	.0248	.0244	.0122
19400	101000	.0383	.0395	.0389	.01945
21100	110000	.0585		.0585	.02975
24000	124500			.15	.075
24200	126000			.17	.085
20000	104000	Broke			

Fracture full cup
Structure slightly granular

Elongation per cent	16.5
Original diam. inches	.495
Final diam. inches	.378
Reduction of area per cent	41.7
Elastic limit lbs.per sq.in.	74000
Max. load lbs.per sq.in.	126000
Modulus of elasticity	30000000
Slerescope	31

FREEMAN AND SNOW

No. 25 .40-.50 Carbon 0875°C. Mineral Oil.



The analysis of specimens Nos.30 to 42 inclusive is as follows :

Carbon	.20-.30 %
Nickel	.70 %
Chromium	.75- 1.25 %
Vanadium added	.16-.20 %
Silicon	.20 %
Manganese	.20-.40 %
Phosporous & Sulphur less than	.04 %

Specimen No. 30.

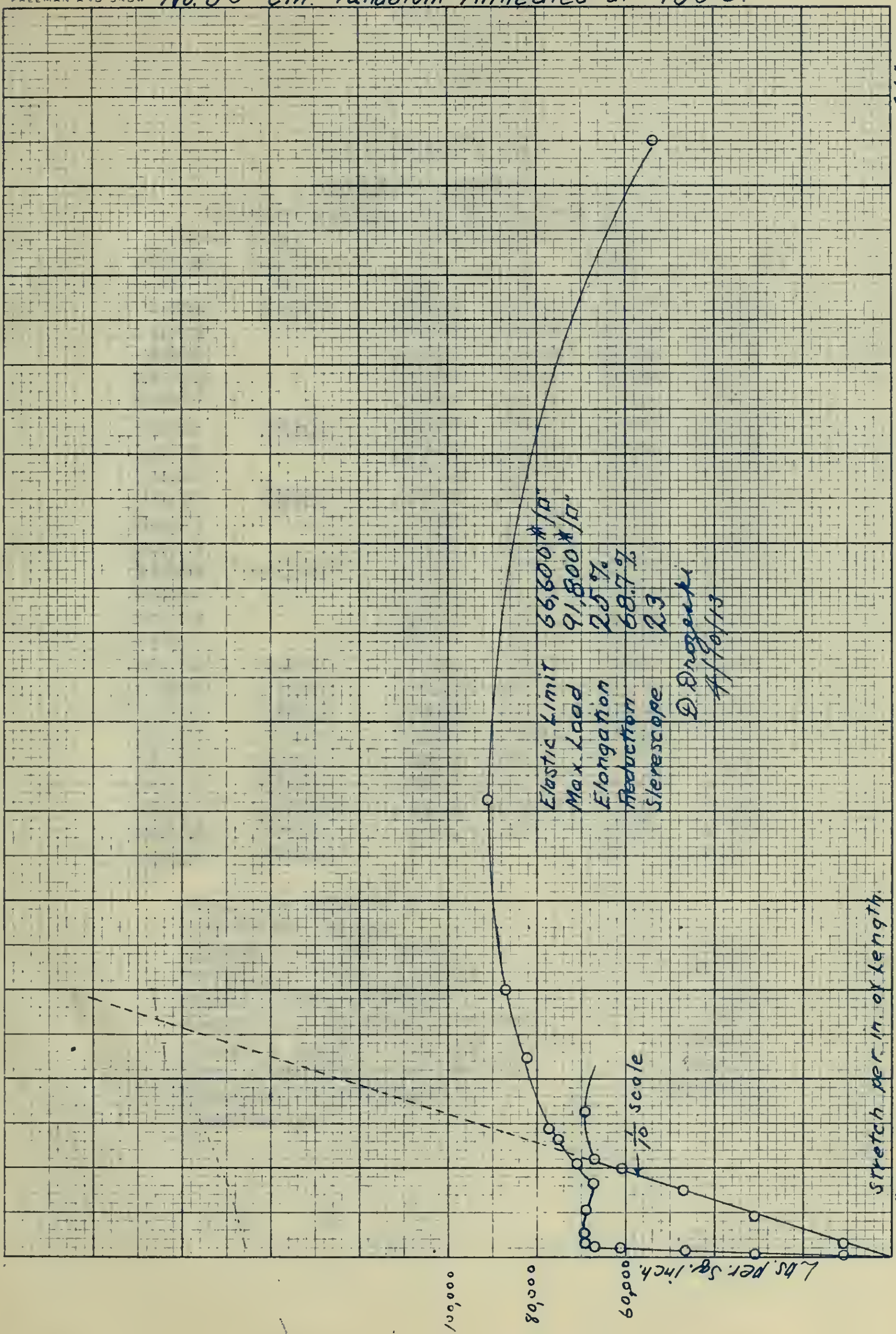
Chrome Vanadium
Annealed at 750 C only.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10250	.0010	.0002	.0006	.0003
44000		.0018	.0009	.0013	.00065
6000	30750	.0023	.0015	.0019	.00095
8000		.0030	.0028	.0026	.0013
9000	46100	.0032	.0028	.0030	.0015
10000		.0036	.0029	.0032	.0016
11000		.0039	.0033	.0036	.0018
12000	61500	.0042	.0038	.0040	.0020
13000	66600	.0047	.0041	.0044	.0022
13500	69200	.0059	.0071	.0065	.00325
13500	69200	.0107	.0112	.0109	.00545
13440	69000	.0210	.0221	.0215	.01075
13100	67200	.0324	.0329	.0326	.0163
14000	71700	.0430	.0408	.0419	.02095
14600	74800	.0516	.0526	.0521	.02605
15100	77400	.0584	.0591	.0587	.02935
16000	82000		.09	.09	.045
17000	87100		.12	.12	.06
17920	91800		.25	.25	.125
10550	54000	Broke			

Fracture square	
Structure silky	
Elongation per cent	25
Original diam. inches	.4985
Final diam. inches	.279
Reduction of area per cent	68.7
Elastic limit lbs.per sq.in.	66600
Max. load lbs.per sq.in.	91800
Modulus of elasticity	31000000
Slerescope	23

FREEMAN AND SNOW

No. 30 Chr. Vanadium Annealed at 750°C.



Elastic Limit 66,600 #/□"
Max. Load 91,800 #/□"
Elongation 25%
Reduction 68.7%
Sclerescope 23

D. Drogeck
4/10/13

Specimen No. 31.

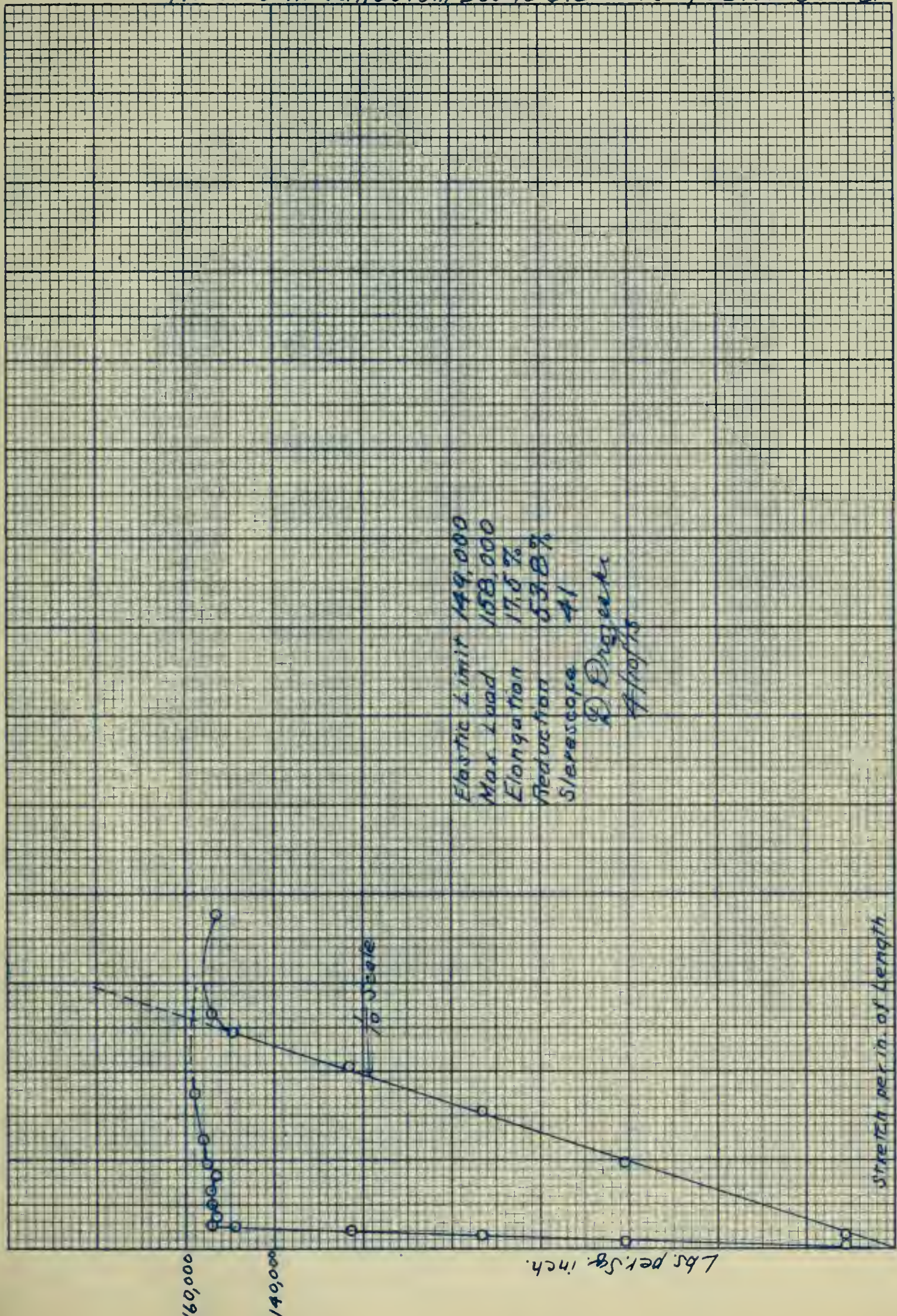
Chrome Vanadium
Double Quench 850 C Single Draw 500 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10250	.0004	.0010	.0007	.00035
4000		.0010	.0018	.0014	.0007
6000		.0018	.0023	.0020	.0010
88000		.0022	.0031	.0026	.0013
10000		.0030	.0039	.0035	.00175
12000	61500	.0036	.0043	.0039	.00195
14000		.0042	.0051	.0046	.0023
16000		.0050	.0060	.0055	.00275
18000	92300	.0058	.0067	.0062	.0031
20000		.0062	.0072	.0067	.00335
22000		.0070	.0080	.0075	.00375
24000	123000	.0078	.0088	.0083	.00415
26000		.0081	.0092	.0086	.0043
27000		.0086	.0099	.0092	.0046
28000		.0090	.0100	.0095	.00475
29000	149000	.0092	.0105	.0098	.0049
30000	154000	.0099	.0113	.0106	.0053
29950	153000	.0140	.0170	.0150	.0075
30080	154000	.0190	.0214	.0202	.0101
30100	154100	.0260	.0280	.0270	.0135
29850	152900	.0315	.0337	.0326	.0163
30200	155000	.0385	.0410	.0397	.01985
30400	156000	.0480	.0509	.0494	.0247
30800	158000			.07	.035

Fracture square	
Structure silky	
Elongation per cent	17.5
Original diam. inches	.4985
Final diam. inches	.300
Reduction of area per cent	53.8
Elastic limit lbs. per sq.in.	149000
Max. load lbs. per sq.in.	158000
Modulus of elasticity	30200000
Slerescope	41

FREEMAN AND SNOW

No. 31 Chr. Vanadium Double Q.850°C. Single Draw 500°C.



Elastic Limit	149,000
Max. Load	158,000
Elongation	17.5 %
Reduction	53.8%
Slerescope	41

D Drozeski
4/10/15

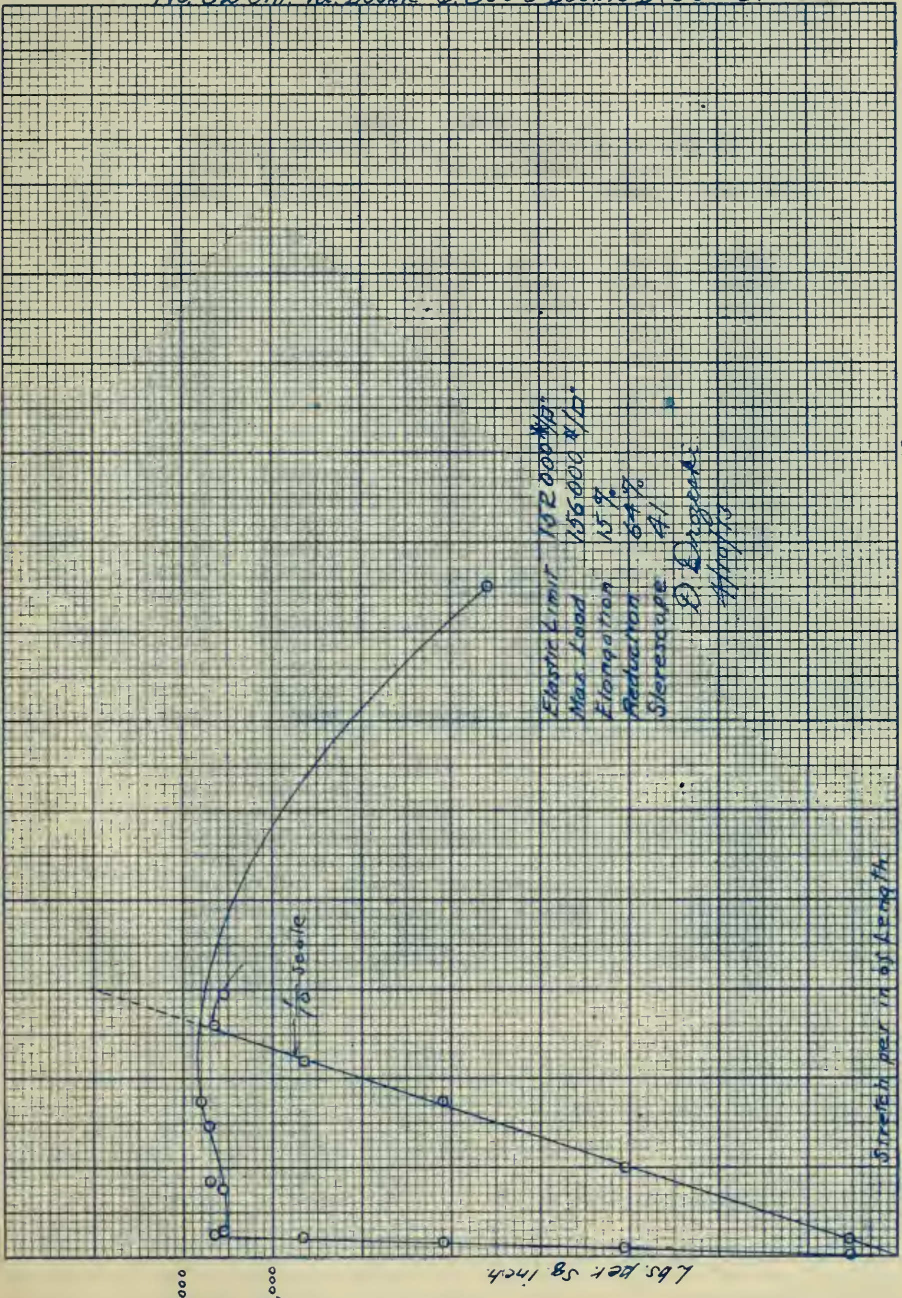
Specimen No. 32.

Chrome Vanadium
Double Quench 850 C Double Draw 500 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in .	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0007	.0009	.0008	.0004
4000		.0012	.0011	.0012	.0006
6000		.0020	.0020	.0020	.0010
8000		.0028	.0027	.0028	.0014
10000		.0032	.0032	.0032	.0016
12000	61400	.0040	.0040	.0040	.0020
14000		.0046	.0049	.0048	.0024
16000		.0053	.0053	.0053	.00265
18000		.0060	.0062	.0061	.00305
20000	102000	.0069	.0070	.0070	.0035
22000		.0073	.0076	.0074	.0037
24000		.0082	.0080	.0081	.00405
26000	133000	.0087	.0090	.0088	.0044
27000		.0090	.0092	.0091	.00455
28000		.0093	.0091	.0092	.0046
29000		.0099	.0102	.0101	.00505
30000	153500	.0111	.0120	.0115	.0057
29600	151500	.0220	.0215	.0118	.0059
29500	151000	.0310	.0320	.0315	.01575
30200	154500	.0420	.0425	.0422	.0161
30500	156000			.07	.035
18000	92000	Broke			

Fracture point	
Structure silky	
Elongation per cent	15
Original diam. inches	.499
Final diam. inches	.300
Reduction of area per cent	64
Elastic limit lbs. per sq.in.	152000
Max. load lbs. per sq.in.	156000
Modulus of elasticity	30000000
Slerescope	41

FREEMAN AND SNOW *No. 32 Chr. Va. Double Q. 850°C Double D. 500°C.*



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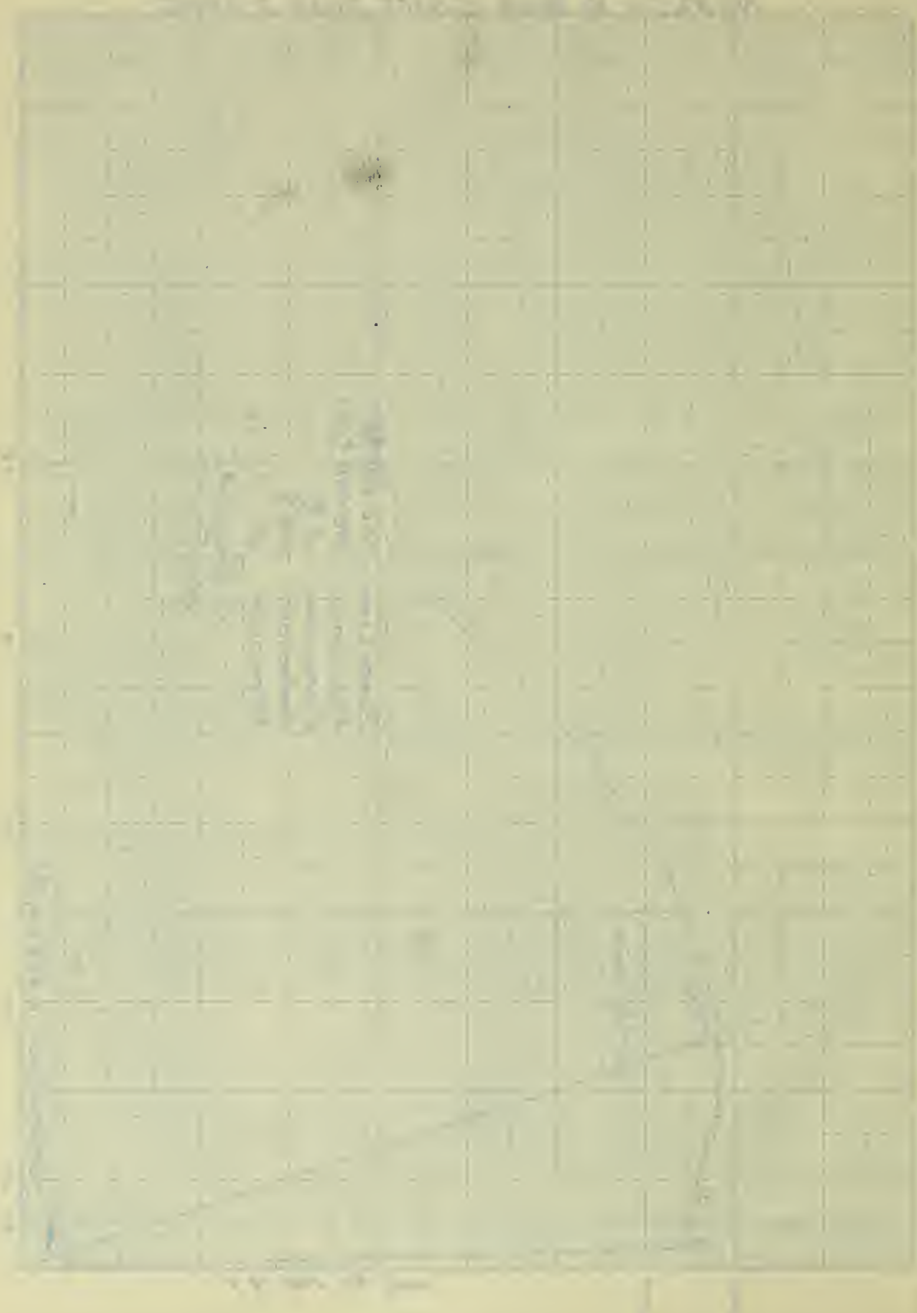

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Specimen No. 33.

Chrome Vanadium

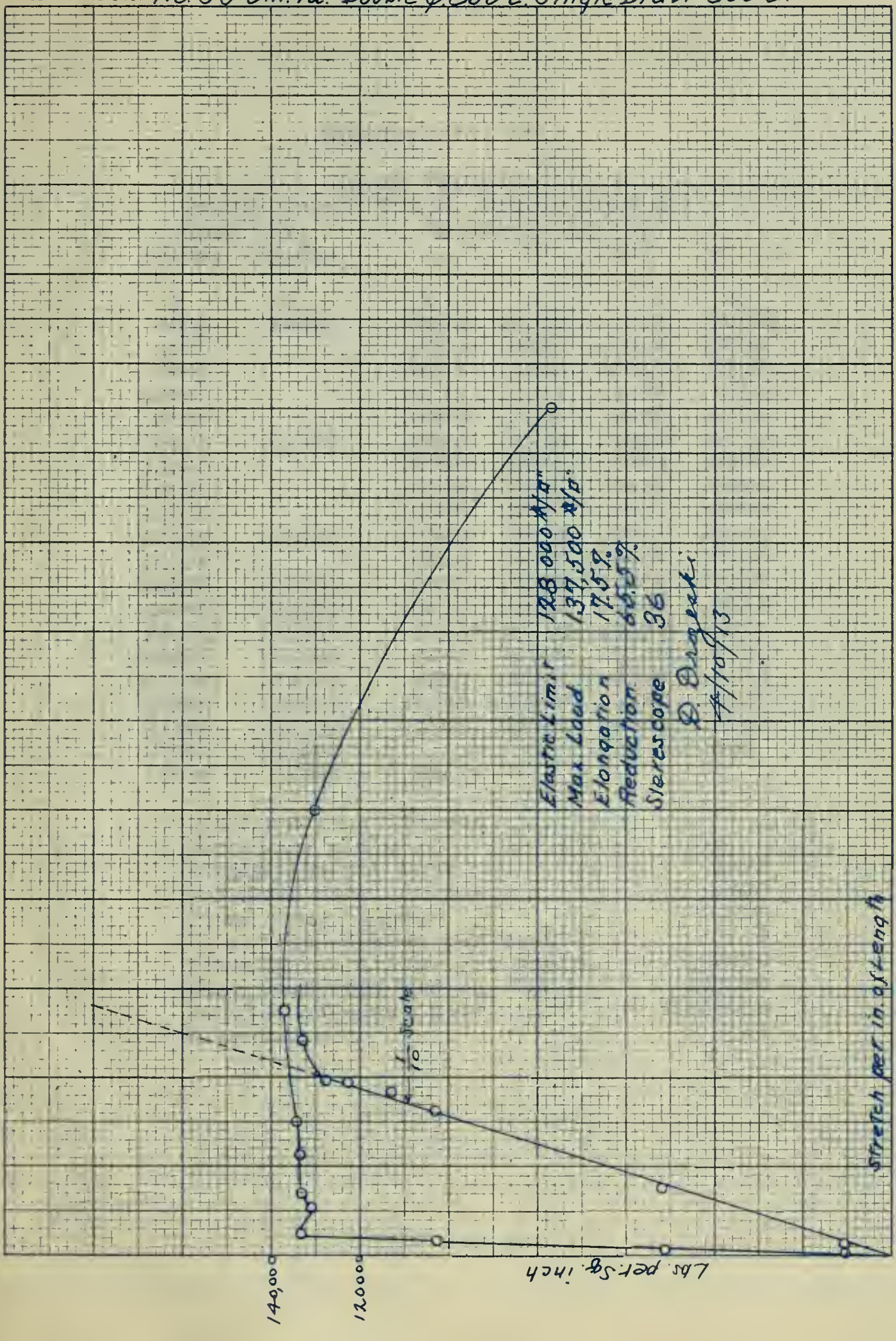
Double Quench 850 C Single Draw 600 C.

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10250	.0003	.0004	.0004	.0002
4000		.0010	.0011	.0010	.0005
6000		.0014	.0020	.0017	.00085
8000		.0021	.0019	.0020	.0010
10000	51300	.0028	.0033	.0030	.0015
12000		.0032	.0041	.0036	.0018
14000		.0040	.0050	.0045	.00225
16000		.0045	.0058	.0051	.00255
18000		.0052	.0065	.0058	.0029
20000	102500	.0060	.0070	.0065	.00325
22000	113000	.0066	.0079	.0072	.00365
24000	123000	.0071	.0085	.0078	.0039
25000	128000	.0075	.0081	.0078	.0039
26000	133500	.0082	.0110	.0096	.0048
25500	131000	.0183	.0220	.0202	.0101
26000	133500	.0262	.0294	.0278	.0139
26000	133500	.0430	.0470	.0450	.0225
26200	134500			.06	.03
26800	137500			.11	.055
15000	77000	Broke			

Fracture long point	
Structure silky	
Elongation per cent	17.5
Original diam. inches	.498
Final diam. inches	.293
Reduction of area per cent	65.5
Elastic limit lbs. per sq.in.	128000
Max. load lbs. per sq.in.	137500
Modulus of elasticity	32200000
Slerescope	36

FREEMAN AND SNOW

No. 33 Chr. Va. Double Q. 850°C. Single Draw 600°C.



Elastic Limit 128 000 #/□"
Max. Load 137,500 #/□"
Elongation 17.5 %
Reduction 65.5 %
Sleresscope 36

D. Drzeski
4/10/13

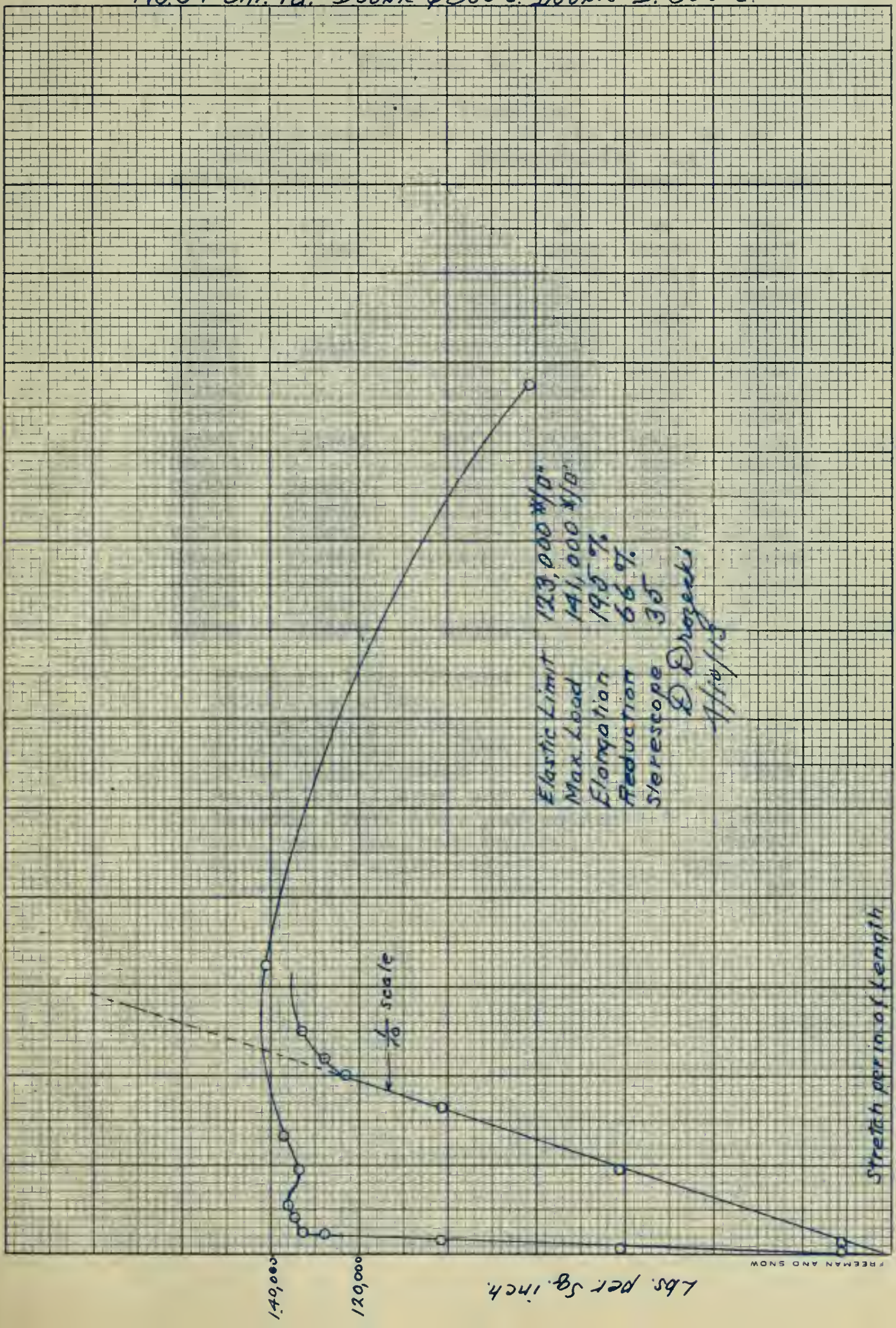
Specimen No. 34.

Chrome Vanadium
Double quench 850 C Double draw 600 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0004	.0006	.0005	.00025
4000		.0009	.0014	.0012	.0006
6000		.0011	.0023	.0017	.00085
88000		.0019	.0031	.0025	.00125
10000		.0023	.0040	.0032	.0016
12000	61400	.0030	.0048	.0039	.00195
14000		.0036	.0053	.0044	.0022
16000		.0042	.0061	.0052	.0026
18000		.0050	.0069	.0059	.00295
20000	102000	.0058	.0073	.0066	.0033
22000		.0064	.0080	.0072	.0036
24000	123000	.0071	.0090	.0080	.0040
25000	128000	.0078	.0098	.0088	.0044
26000	133000	.0085	.0116	.0100	.0050
26300	134500	.0148	.0188	.0168	.0084
26500	136000	.0200	.0240	.0220	.0110
26200	134000	.0365	.0398	.0382	.0191
26700	137000	.0505	.0542	.0524	.0262
27500	141000			.13	.065
16000	81800	Broke			

Fracture long fibrous	
Structure silky	
Elongation per cent	19.5
Original diam. inches	.499
Final diam. inches	.291
Reduction of area per cent	66
Elastic limit lbs. per sq.in.	123000
Max. load lbs. per sq. in.	141000
Modulus of elasticity	31000000
Slerescope	35

No. 34 Chr. Va. Double Q 850°C. Double D. 600°C.



Elastic Limit 123,000 #/□"
Max. Load 141,000 #/□"
Elongation 19.5 %
Reduction 66 %
Sterescope 35
D Drozecki
1/10/15

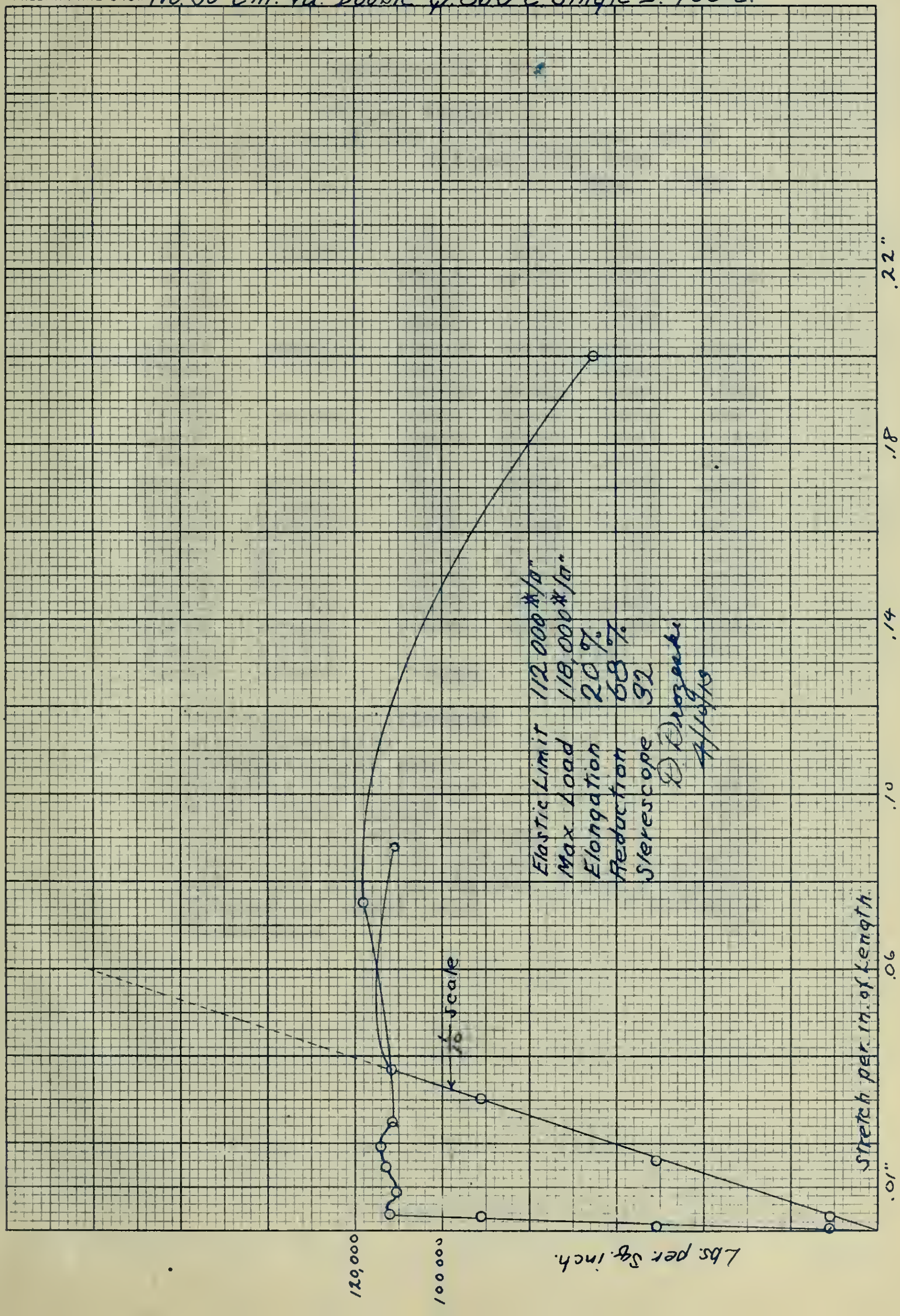
Specimen No. 35

Chrome Vanadium
Double Quench 850 C Single Draw 700 C

Load Lbs. Actual	Sq.in.	Extensometer ins. L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0010	.0002	.0006	.0003
4000		.0019	.0008	.0014	.0007
6000		.0026	.0011	.0019	.00095
8000		.0033	.0019	.0026	.0013
10000	51000	.0041	.0023	.0032	.0016
12000		.0050	.0030	.0040	.0020
14000		.0059	.0035	.0047	.00235
16000		.0068	.0041	.0055	.00275
18000	91700	.0074	.0049	.0062	.0031
20000		.0081	.0053	.0067	.00335
22000	112000	.0090	.0060	.0075	.00375
21700	110500	.0196	.0141	.0168	.0084
22100	113000	.0320	.0256	.0288	.0144
22400	114000	.0430	.0340	.0385	.01925
22000	112000		.0492	.0492	.0246
23200	118000			.15	.075
12800	65500	Broke			

Fracture long fibrous	
Structure silky	
Elongation per cent	20
Original diam. inches	.500
Final diam. inches	.283
Reduction of area per cent	68
Elastic limit lbs. per sq.in.	112000
Max. load lbs. per sq. in.	118000
Modulus of elasticity	30000000
Slerescope	32

FREEMAN AND SNOW No. 35 Chr. Va. Double Q. 850°C. Single D. 700°C.



Elastic Limit	112,000 #/□"
Max. Load	118,000 #/□"
Elongation	20 %
Reduction	68 %
Stereoscope	92

4/14/19

Specimen No. 36.

Chrome Vanadium

Double Quench 850 C Double Draw 700 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10400	.0010	.0003	.0006	.0003
4000		.0016	.0010	.0013	.00065
6000		.0022	.0017	.0018	.0009
8000		.0030	.0022	.0026	.0013
10000	52000	.0038	.0030	.0034	.0017
12000		.0044	.0037	.0040	.0020
14000		.0052	.0042	.0047	.00235
16000	83200	.0060	.0050	.0055	.00275
18000		.0069	.0057	.0063	.00315
19000		.0071	.0060	.0066	.0033
20000	104000	.0074	.0062	.0068	.0034
21000	109000	.0081	.0070	.0076	.0038
21000	109000	.0100	.0080	.0090	.0045
20700	107500	.0140	.0110	.0125	.00625
21100	109500	.0200	.0170	.0185	.00925
21300	111000	.0430	.0425	.0428	.0214
20700	107500	.0598	.0582	.0590	.0295
222000	115000			.17	.085
12350	64200	Broke			

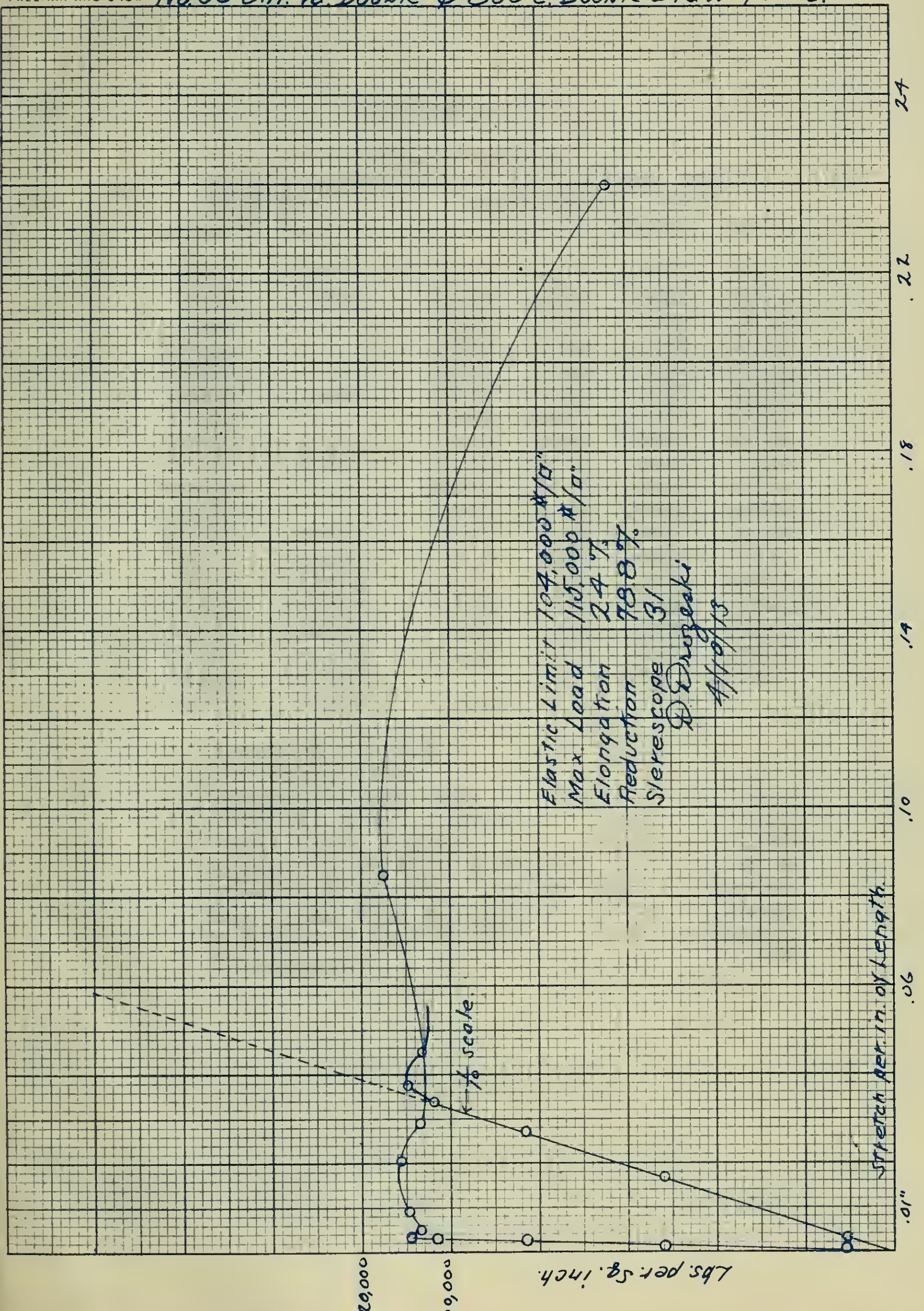
Fracture short fibrous

Structure silky

Elongation per cent	24
Original diam. inches	.495
Final diam. inches	.277
Reduction of area per cent	78.8
Elastic limit lbs. per sq.in.	104000
Max. load lbs. per sq.in.	115000
Modulus of elasticity	30500000
Slerescope	31

FREEMAN AND SNOW

No. 36 Chr. Va. Double Q 850°C. Double Draw 700°C.



Elastic Limit 104,000 #/□"
Max. Load 115,000 #/□"
Elongation 24 %
Reduction 78.8 %
Sleroscope 31
D. Drozeski
4/10/13

Specimen No. 37.

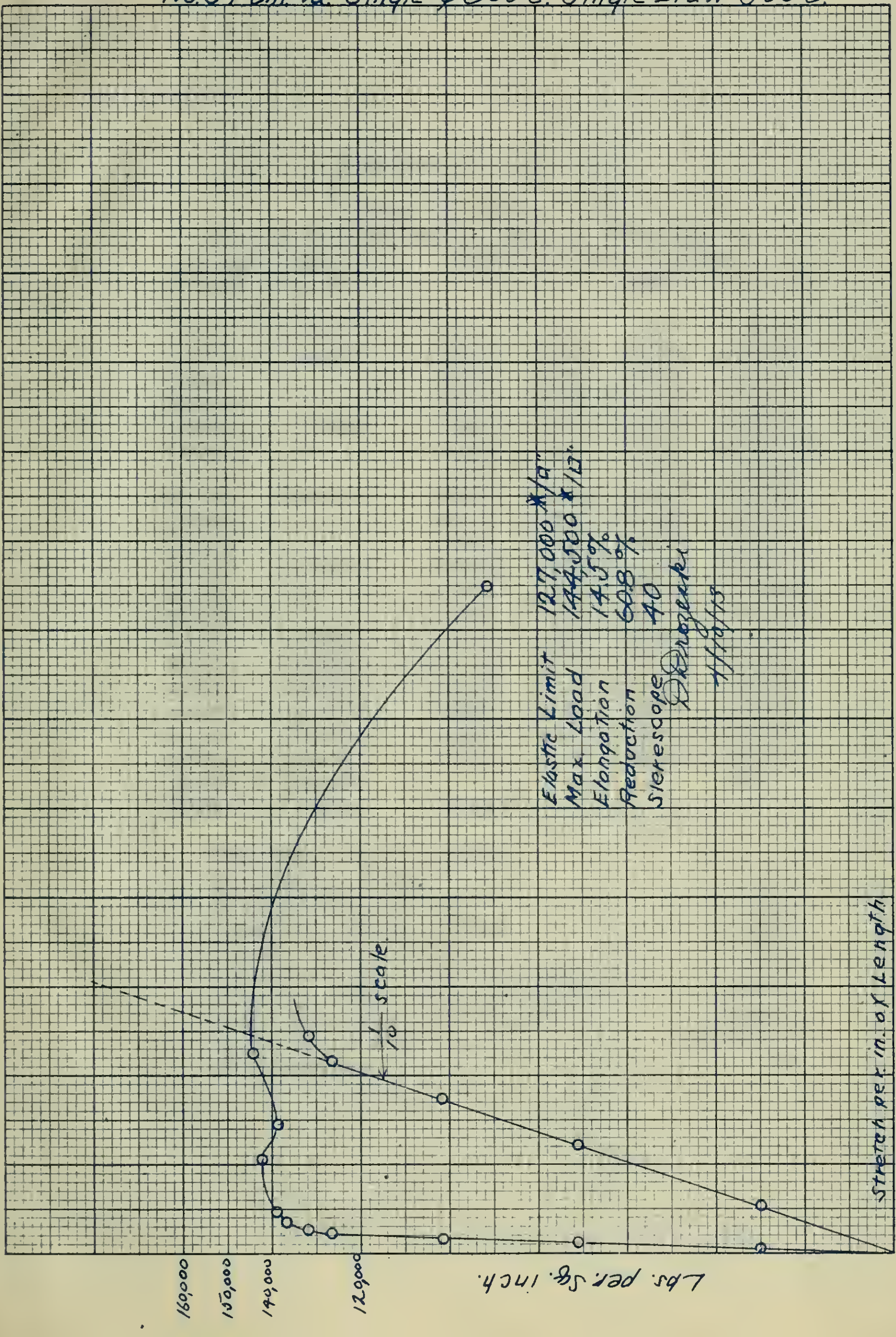
Chrome Vanadium
Single Quench 850 C Single Draw 500 C

Load Lbs.		Extensometer ins.			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
6000	30500	.0013	.0030	.0022	.0011
8000		.0021	.0037	.0029	.00145
10000		.0029	.0042	.0036	.0018
12000		.0033	.0050	.0042	.0021
14000	71300	.0041	.0056	.0049	.00245
16000		.0050	.0061	.0056	.0028
18000		.0059	.0069	.0064	.0032
20000	102000	.0065	.0073	.0069	.00345
22000		.0072	.0079	.0076	.0038
24000		.0080	.0088	.0084	.0042
25000	127000	.0083	.0091	.0087	.00435
26000	132000	.0093	.0103	.0098	.0049
27000	137000	.0133	.0150	.0142	.0071
27300	139000	.0180	.0198	.0189	.00945
28000	142500	.0423	.0440	.0432	.0216
28300	139000	.0590	.0600	.0595	.02975
28400	144500			.09	.045
18000	91700	Broke			

Fracture 7/8 cup	
Structure silky	
Elongation per cent	14.5
Original diam. inches	.1963
Final diam. inches	.313
Reduction of area per cent	60.8
Elastic limit lbs. per sq. in.	127000
Max. load lbs. per sq.in.	144500
Modulus of elasticity	29500000
Slerescope	40

FREEMAN AND SNOW

No. 37 Chr. Va. Single Q 850°C. Single Draw 500°C.



Elastic Limit 127,000 #/□"
Max. Load 144,500 #/□"
Elongation 14.5 %
Reduction 60.8 %
Sclerescope 40
1/1/15

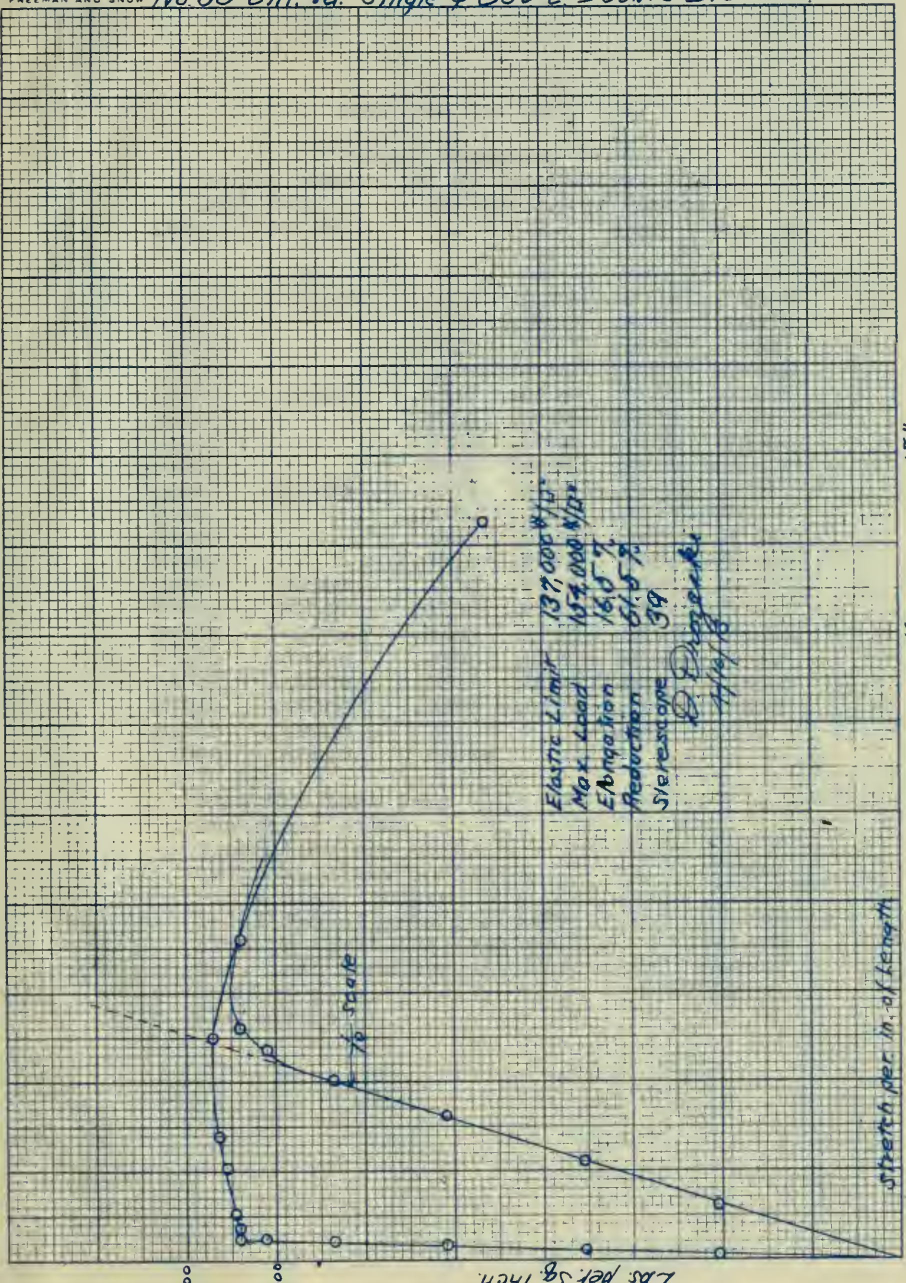
Specimen No. 38.

Chrome Vanadium
Single Quench 850 C Double Draw 500 C

Load Lbs.		Extensometer	Inches		
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
8000	40700	.0021	.0029	.0025	.00125
10000		.0029	.0032	.0030	.0015
12000		.0035	.0040	.0038	.0019
14000	71300	.0042	.0046	.0044	.0022
16000		.0051	.0051	.0051	.00255
18000		.0069	.0069	.0069	.00345
20000	102000	.0066	.0064	.0065	.00325
22000		.0072	.0071	L0071	.00355
24000		.0080	.0077	.0078	.0039
25000	127000	.0082	.0079	.0081	.00405
26000		.0089	.0081	.0085	.00425
27000		.0092	.0086	.0089	.00445
28000	142500	.0100	.0090	.0095	.00475
29000	148000	.0113	.0095	.0104	.0052
29000	148000	.0154	.0133	.0144	.0072
29300	149000	.0220	.0200	.0210	.0105
29800	151500	.0428	.0400	.0414	.0207
30000	153000	.0580	.0540	.0550	.0280
30200	154000			.10	.05
18200	92700	Broke			

Fracture short point	
Structure silky	
Elongation per cent	16.5
Original diam. inches	.500
Final diam. inches	.310
Reduction of area per cent	61.5
Elastic limit lbs.per sq.in.	137000
Max. load lbs. per sq.in.	154000
Modulus of elasticity	31600000
Slerescope	39

FREEMAN AND SNOW No. 38 Chr. Va. Single Q 850°C Double D. 500°C.



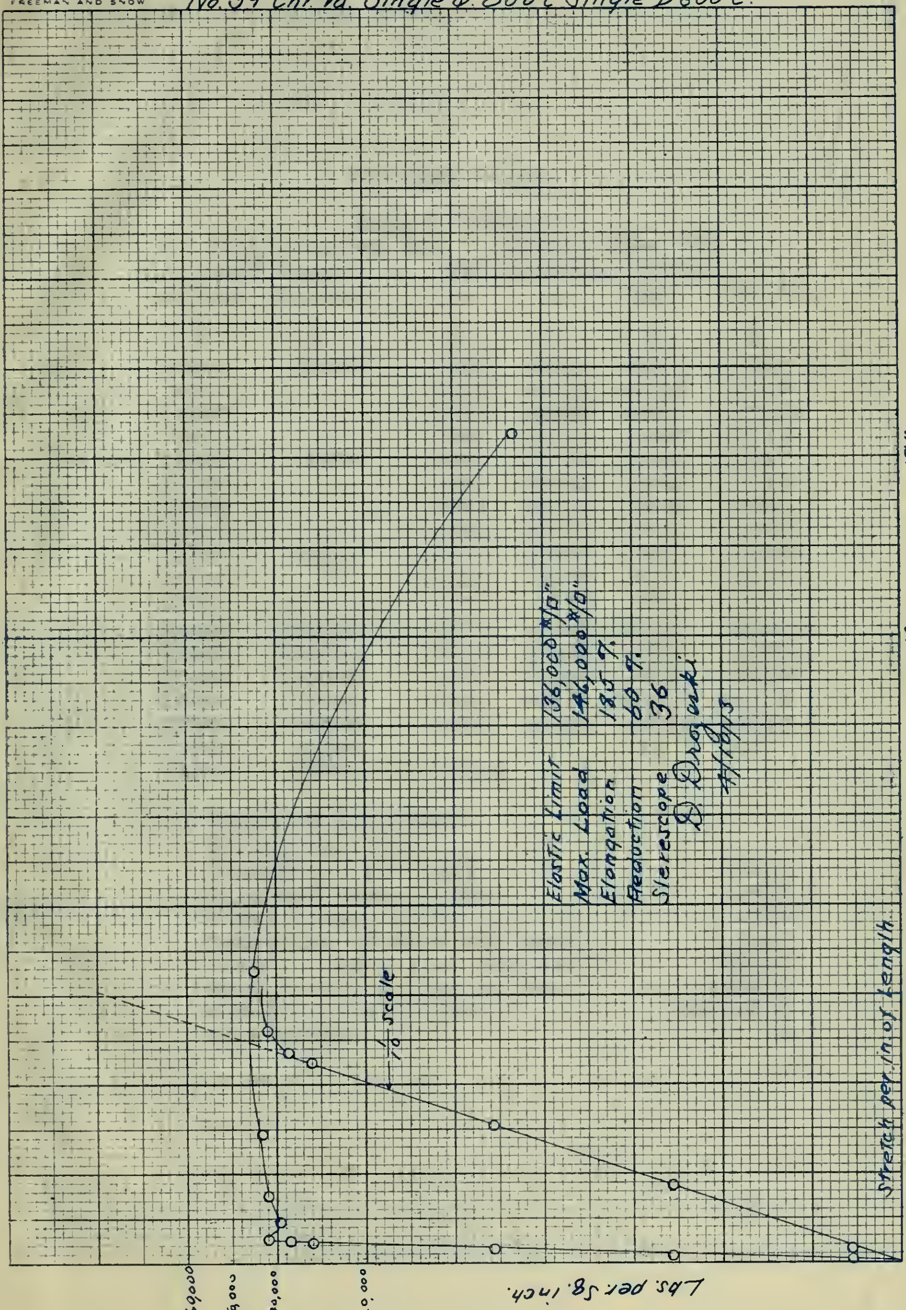
Specimen No. 39.

Chrome Vanadium
Single Quench 850 C Single draw 600 C

Load Lbs.		Extensometer inches			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10150	.0010	.0003	.0007	.00035
4000		.0020	.0010	.0015	.00075
6000		.0026	.0014	.0020	.0010
8000		.0033	.0021	.0027	.00135
10000	50800	.0041	.0029	.0035	.00175
12000		.0050	.0033	.0042	.0021
14000		.0058	.0040	.0049	.00245
16000		.0062	.0048	.0055	.00275
18000	91500	.0071	.0053	.0062	.0031
20000		.0088	.0060	.0074	.0037
22000		.0083	.0069	.0076	.0038
24000		.0091	.0071	.0081	.00405
26000	132000	.0100	.0080	.0090	.0045
27000	137000	.0105	.0083	.0094	.0047
28000	142000	.0120	.0090	.0105	.00525
27400	139000	.0195	.0170	.0182	.0091
28000	142000	.0312	.0288	.0300	.0150
28200	143000	.0590	.0562	.0576	.0288
28700	146000			.13	.065
17000	86300	Broke			

Fracture long tean	
Structure silky	
Elongation per cent	18.5
Original diam. inches	.1971
Final diam. inches	.317
Reduction of area per cent	60
Elastic limit lbs. per sq.in.	136000
Max. load lbs. per sq.in.	146000
Modulus of elasticity	29500000
Slerescope	36

No. 39 Chr. Va. Single Q. 850°C Single D 600°C.



Elastic Limit 136,000 #/□"
Max. Load 146,000 #/□"
Elongation 18.5 %
Reduction 60 %
Scleroscope 36

Specimen No.40.

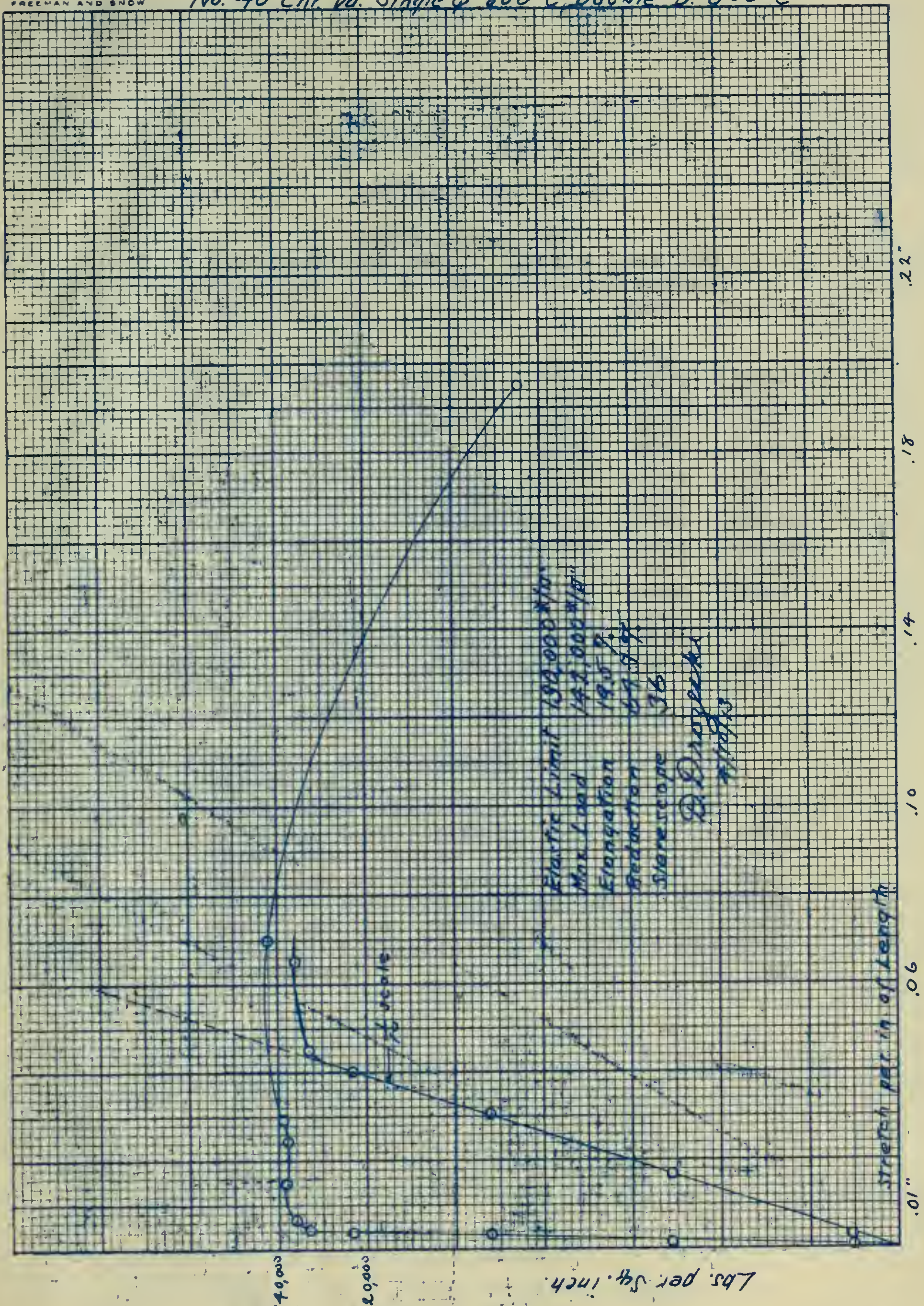
Chrome Vanadium
Single Quench 850 C Double Draw 600 C

Load Lbs.		Extensometer inches			
Actual	Sq.in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10300	.0005	.0007	.0006	.0003
4000		.0010	.0014	.0012	.0006
6000		.0016	.0022	.0019	.00095
8000		.0022	.0030	.0026	.0013
10000	51300	.0030	.0038	.0034	.0017
12000		.0033	.0043	.0038	.0019
14000		.0041	.0051	.0046	.0023
16000		.0058	.0050	.0054	.0027
18000	92500	.0056	.0066	.0061	.00305
20000		.0062	.0070	.0066	.0033
22000		.0071	.0077	.0074	.0037
24000	123000	.0078	.0082	.0080	.0040
26000	133000	.0088	.0092	.0090	.0090
26500	136000	.0128	.0134	.0131	.00655
26900	138000	.0305	.0310	.0303	.0154
27100	139000	.0590	.0582	.0586	.0293
27700	142000			.14	.07
16500	84700	Broke			

Fracture long tear	
Structure silky	
Elongation per cent	19.5
Original diam. inches	.498
Final diam. inches	.296
Reduction of area per cent	64.7
Elastic limit lbs. per sq.in.	130000
Max. load lbs. per sq.in.	142000
Modulus of elasticity	30500000
Slerescope	36

FREEMAN AND SNOW

No. 40 Chr. Va. Single Q 850°C Double D. 600°C



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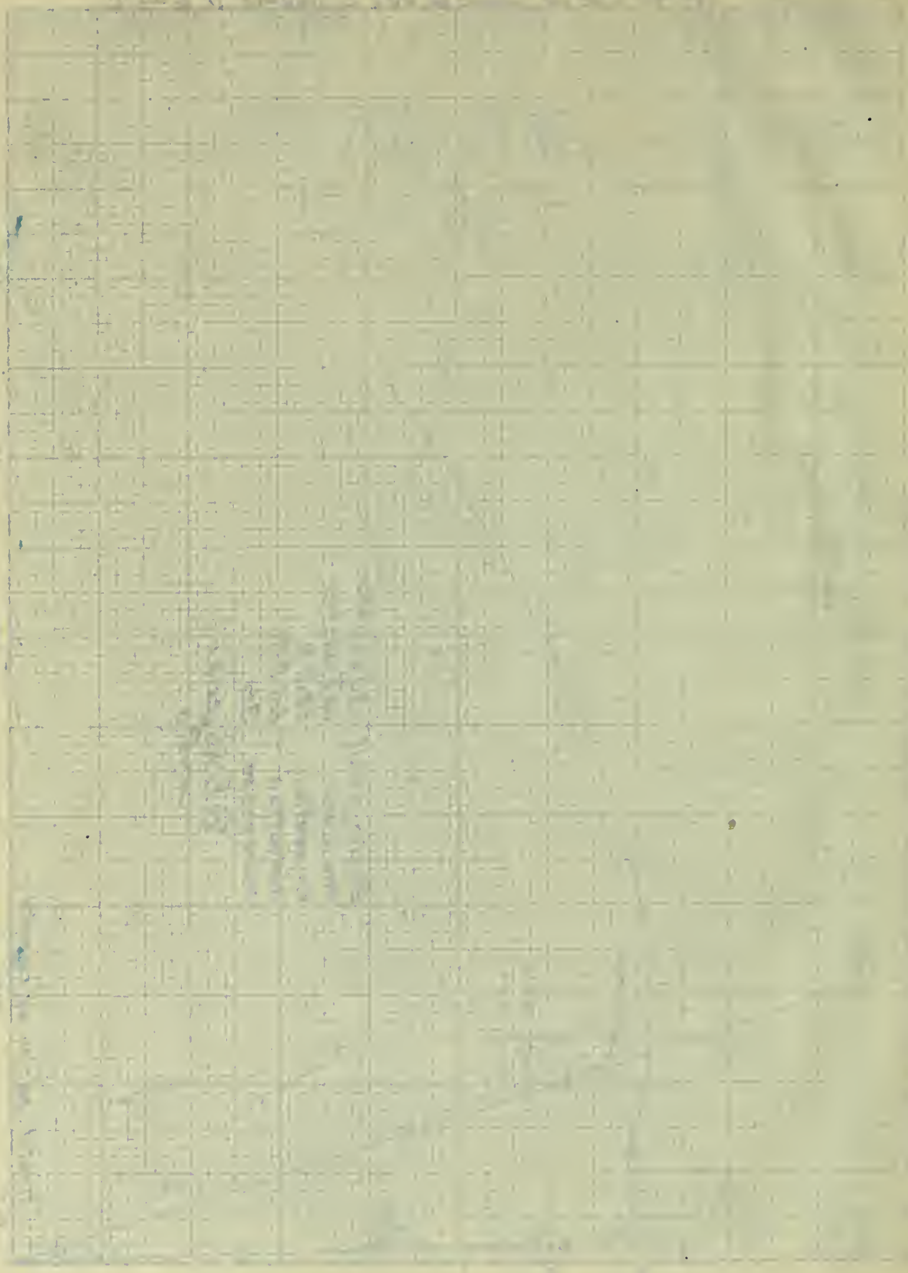


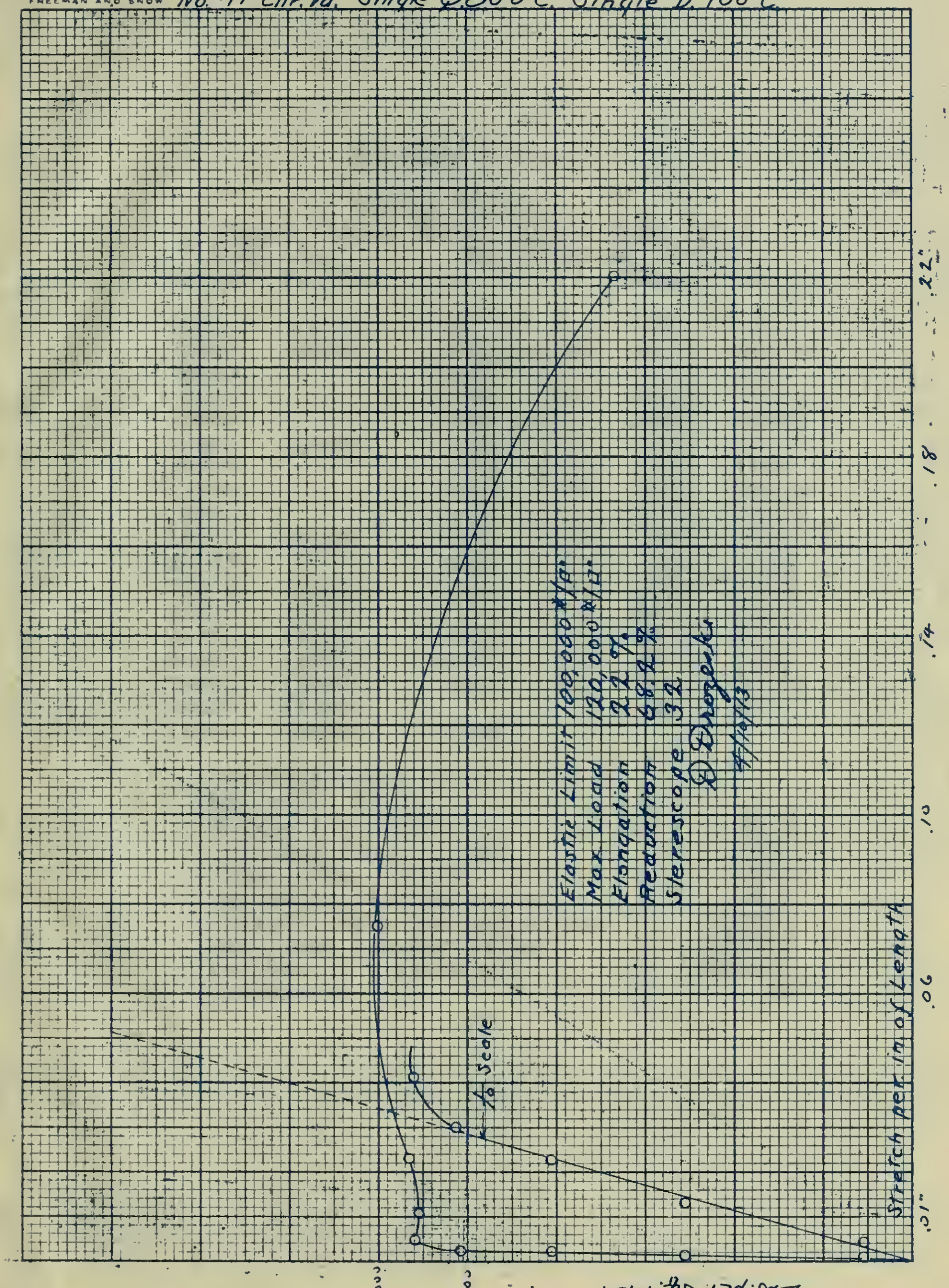
Specimen No. 41.

Chrome Vanadium
Single Quench 850 C Double Draw 700 C

Load Lbs.		Extensometer inches			
Actual	Sq. in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10200	.0006	.0008	.0009	.00045
4000		-.0005	.0018	.0006	.0003
6000		.0000	.0023	.0012	.0006
8000		.0008	.0030	.0019	.00095
10000	51000	.0013	.0039	.0026	.0013
12000		.0020	.0042	.0031	.00155
14000		.0028	.0050	.0039	.00195
16000	81500	.0032	.0058	.0045	.00225
18000		.0040	.0062	.0051	.00255
20000	102000	.0050	.0070	.0060	.0030
22000	112000	.0075	.0091	.0083	.00415
21900	111000	.0196	.0241	.0218	.0109
22200	113000	.0490	.0458	.0474	.0237
23500	120000			.15	.075
132000	67300	Broke			

Fracture short point	
Structure silky	
Elongation per cent	22
Original diam. inches	.500
Final diam. inches	.282
Reduction of area per cent	68.2
Elastic limit lbs. per sq.in.	100000
Max. load lbs. per sq.in.	120000
Modulus of elasticity	35300000
Sleroscope	32

FREEMAN AND SNOW No. 41 Chr. Va. Single Q. 850°C. Single D. 700°C.



Elastic Limit 100,000 #/□"
Max Load 120,000 #/□"
Elongation 22 %
Reduction 68.2 %
Sclerescope 32
D. Drozek
4/14/13

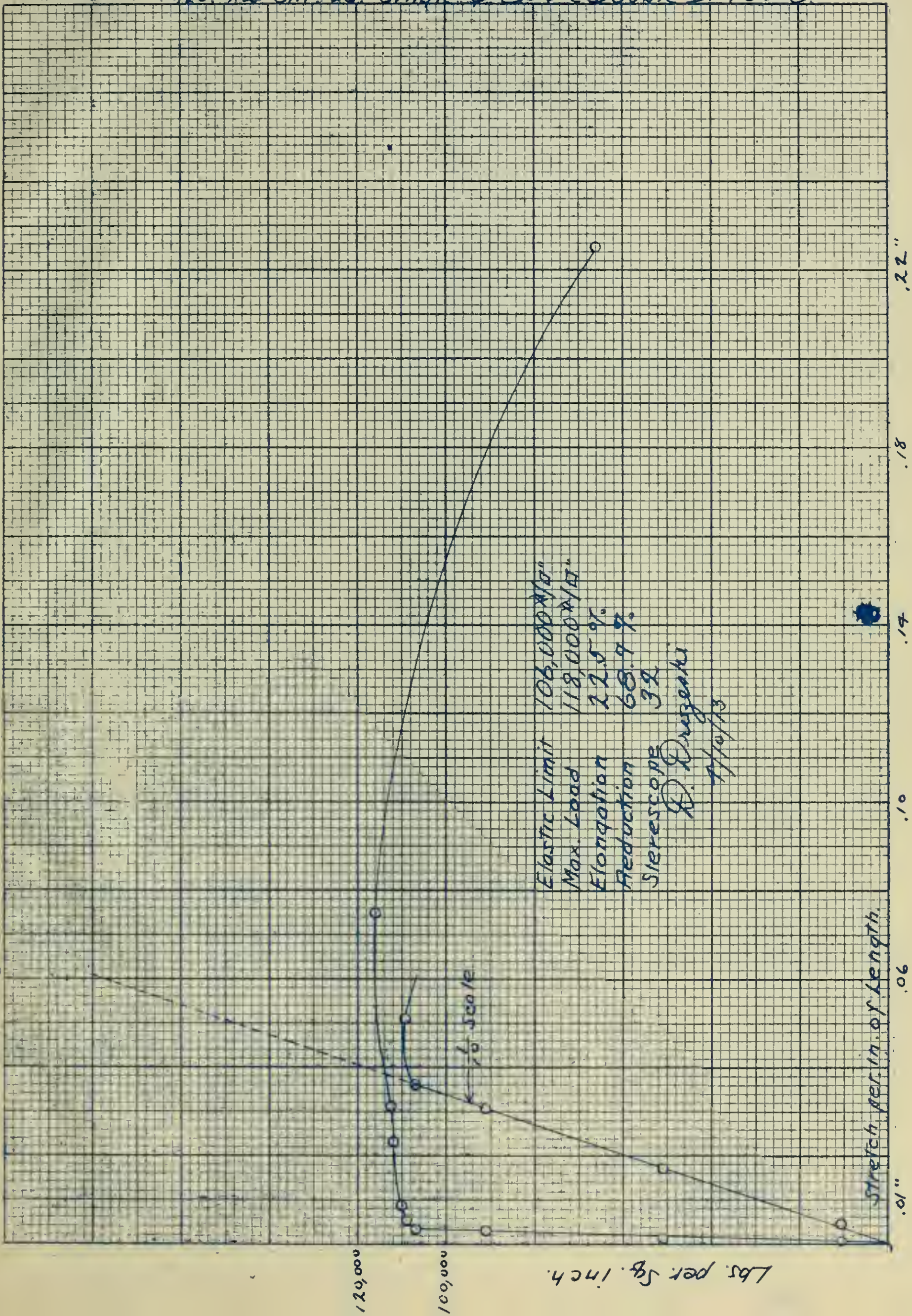
Specimen No. 42.

Chrome Vanadium
Single Quench 850 C Double Draw 700 C

Load Lbs.		Extensometer inches			
Actual	Per in.	L.	R.	Mean	Per in.
0	0	0	0	0	0
2000	10150	.0020	-.0002	.0009	.00045
4000		.0028	.0000	.0014	.0007
6000		.0032	.0008	.0020	.0010
8000		.0040	.0014	.0027	.00135
10000	50800	.0048	.0022	.0035	.00175
12000		.0052	.0030	.0041	.00205
14000		.0060	.0038	.0049	.00245
16000		.0066	.0044	.0055	.00275
18000	91400	.0072	.0050	.0061	.00305
20000		.0080	.0060	.0070	.0035
21000	106500	.0081	.0062	.0072	.0036
21500	109000	.0114	.0092	.0103	.00515
21700	110000	.0228	.0118	.0173	.00865
22000	112000	.0472	.0468	.0470	.0235
22200	112500	.0640	.0602	.0621	.03105
23200	118000			.15	.075
13000	66000	Broke			

Fracture short point	
Structure silky	
Elongation per cent	22.5
Original diam. inches	.501
Final diam. inches	.280
Reduction of area per cent	68.7
Elastic limit lbs.per sq.in.	106000
Max. load lbs.per sq.in.	118000
Modulus of elasticity	29500000
Slerescope	32

No. 42 Chr. Va. Single Q. 850°C Double D. 700°C.



Elastic Limit 108,000 #/□"
Max. Load 118,000 #/□"
Elongation 22.5 %
Reduction 68.9 %
Sleroscope 32
R. Drzezoki
4/10/13